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IMPROVEMENT OF TELEVISED INSTRUCTION BASED ON STUDENT RESPONSES TO ACHIEVEMENT TESTS. STUDIES IN TELEVISED INSTRUCTION, REPORT 1.
BY- GROPPER, GEORGE L.   AND OTHERS
METROPOLITAN PITTSBURGH EDUC. TV STATION, PA.
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A SERIES OF EXPERIMENTS WAS CONDUCTED TO TEST THE EFFECTIVENESS OF TELEVISED INSTRUCTION. THIS REPORT, THE FIRST IN A SERIES, STUDIES THE APPLICATION OF PRETESTING PROCEDURES TO BROADCAST TELEVISION. EXPERIMENTAL COMPARISONS WERE MADE OF THE EFFECTIVENESS OF A PREVIEW VERSION OF A TELEVISED LESSON AND ITS REVISED COUNTERPART. THE EXPERIMENT WAS REPLICATED USING DIFFERENT LESSON CONTENT ON HEAT, ONE ON CHEMISTRY, DIFFERENT INSTRUCTORS, AND DIFFERENT CLASSES OF STUDENTS. EACH LESSON WAS A PREVIEW SHOWING FOLLOWED BY AN ACHIEVEMENT TEST. ANALYSES OF TEST ITEMS REVEALED WHAT WAS NOT BEING TAUGHT EFFECTIVELY. LESSONS WERE REVISED ACCORDINGLY. LATER, PREVIEW AND REVISED VERSIONS OF THE LESSON WERE TELECAST SIMULANEOUSLY. STUDENTS WERE THEN TESTED. RESULTS SHOWED AN AVERAGE IMPROVEMENT VARYING FROM 6 TO 26 PERCENT FOR STUDENTS WHO WATCHED THE REVISED VERSION OVER STUDENTS WHO WATCHED THE ORIGINAL, PREVIEW VERSION. TEST RESULTS FOLLOWING A LESSON PREVIEW WERE CONSIDERED AN EFFECTIVE SUBSTITUTE FOR STUDENT-TEACHER INTERACTION. TELEVISION ENABLED THE INSTRUCTOR TO TAILOR HIS PRESENTATION TO THE NEEDS AND ABILITIES OF HIS PARTICULAR STUDENT AUDIENCE. RELATED REPORTS ARE ED 003 646 THROUGH ED 003 653. (HB)

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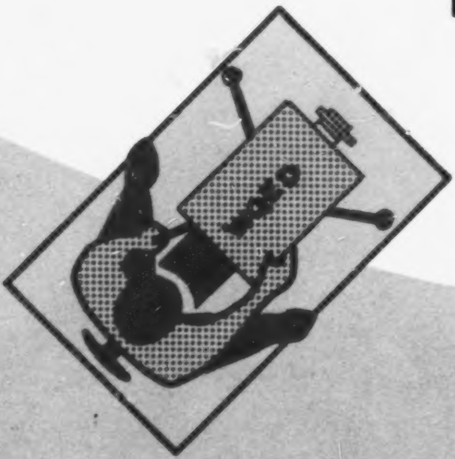
STUDIES IN
TELEVISED INSTRUCTION

IMPROVEMENT OF TELEVISED INSTRUCTION BASED ON STUDENT RESPONSES TO ACHIEVEMENT TESTS



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PITTSBURGH, PENNSYLVANIA

AIR-C13-61-FR-245(I)

STUDIES IN TELEVISED INSTRUCTION

Report Number 1

IMPROVEMENT OF TELEVISED INSTRUCTION BASED ON STUDENT RESPONSES TO ACHIEVEMENT TESTS

Studies in
Televised
Instruction,
Report 1.

George L. Gropper
Arthur A. Lumsdaine
and
Virginia Shipman

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Metropolitan Pittsburgh Educational Television Stations
WQED-WQEX

and

American Institute for Research
Pittsburgh, Pennsylvania
March 1961

OVERVIEW

This is one of a series of reports on studies that use student responses to improve televised instruction. In these studies student response was used in three different ways. All three kinds of use shared the common objective of utilizing student responses to provide tangible, measurable indications of the adequacy of instructional procedures for attaining the educational goals of TV lessons.

1. USE OF STUDENT RESPONSE

... To Pre-test a TV Lesson

Student responses on an achievement test following a preview showing of a TV lesson were used as a basis for preparing a revised version of the lesson. Student performance on each test question indicated which points were fairly well learned and which points were not. This information provided useful feedback to the TV instructor, guiding him in the preparation of a more effective revision of his lesson.

2. USE OF STUDENT RESPONSE

... To Evaluate "Programming" Adequacy

... To Enhance Learning Effectiveness

"Programming" techniques derived from research on self-instructional devices were applied in the preparation of TV lessons. A primary purpose of these techniques was to facilitate correct responses by students. Procedures were designed to elicit active responding throughout the lesson. Students' ability to respond correctly provided evidence of how adequately the lesson sequences were programmed. Also, when students were encouraged to make frequent active responses to lessons programmed so they could respond correctly, the effectiveness of the lessons was significantly increased. Student responding was thus used first, to indicate the adequacy of lesson programming and second, to increase lesson effectiveness.

...To Evaluate Incentive Created by a TV Lesson

A TV lesson was designed to stimulate student follow-up activity. Students were encouraged to perform experiments at home that they had seen demonstrated on TV. Student responses in performing experiments at home on their own indicated the effectiveness of the TV lesson in providing an incentive for follow-up activity.

Much of the responsibility for attaining the instructional objectives of a TV lesson rests with TV teachers and producers. Student responses can be considered as the building blocks of the program. This means devising instructional procedures that will elicit appropriate responses, and judging these procedures as adequate only when students do, in fact, respond appropriately. This kind of careful and systematic attention to student responses should contribute strongly to the successful attainment of educational objectives.

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The report presented in this volume illustrates the use of student responses to pre-test and improve a TV lesson.

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ABSTRACT

Experimental comparisons were made of the instructional effectiveness of a preview version of a lesson and its revised counterpart. The primary purpose of the study was to demonstrate the value for student learning of pretesting a lesson and revising it on the basis of achievement test results.

The experiment was replicated using different lesson content (a lesson on "heat" and a lesson on "chemistry"), different instructors, and different classes of students. Each lesson was given a preview showing followed by the administration of an achievement test. Analyses of test items revealed which points were not effectively taught. Lessons were revised accordingly.

At a later date preview and revised versions of the lesson were simultaneously telecast. Students who watched each version took an identical test. Results showed an average improvement varying from six to twenty-six percent for students who watched the revised version over students who watched the original, preview version. Most of the experimental comparisons made were statistically significant.

Test results following a preview of a lesson, it is concluded, are an effective substitute for the interaction between student and teacher that occurs in a classroom. It enables the TV instructor to tailor his presentation to the needs and abilities of his particular student audience.

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INTRODUCTION

Immediate student reaction to classroom instruction provides the teacher with a basis for maintaining needed flexibility in presenting instruction. With the aid of immediate student response to his presentation, the classroom instructor is able to adapt his material to the needs and abilities of his students. He can repeat, restate, or rephrase points that students' responses show they do not understand. He can alter or clarify the points they misconstrue. Moreover, he can answer the questions they raise. In this way the teacher has the opportunity to maintain active control over and give needed direction to the learning behavior of his students. The TV instructor does not enjoy this flexibility. Moreover, since his presentation affects many more students, the lack of feedback can be much more serious quantitatively than it is for presentation to a single class.

In one sense the TV instructor does experience a "live" audience reaction. It consists of instructions from the director or signals from stagehands and technicians in the studio. He learns where to stand, when to begin, or how to face the camera. But the audience he is more vitally concerned with consists of students in the classroom, and from them he can ordinarily get no immediate reaction. He cannot observe their responses which would indicate that they understood certain points and failed to understand other points. While the lesson is in progress he has no basis for deciding how to alter his presentation so the lesson will be better understood. He loses the opportunity to guide the learning behavior of his students as needed. Since this instructional advantage, often available in classroom instruction, is not open to him, the TV instructor loses an important asset. In consequence, the quality and effectiveness of his instruction, as measured by student achievement, may well be less than optimal.

This problem was recognized early in research on instructional films and educational television. The absence of face-to-face interaction of teacher and pupil with the resulting loss of teacher control over the learning behavior of pupils applies to both media. In response to this challenge, there have been a number of mechanical and procedural innovations modifying the production and use of instructional films and television.

Previous attempts to improve feedback to the instructor

There have been three approaches for providing feedback to TV instructors. One of these approaches has been the development of two-way communication systems enabling TV instructors to ask questions of students watching the televised lessons in classrooms physically remote from the studio (4, 7, 13, 14, & 15). More important, students have been able to ask questions of the TV instructor. This interaction capability provides the instructor with an opportunity to make an on-the-spot evaluation of how well students understand lesson material. When necessary, he can try to determine what changes in his presentation will lead to improved student understanding. A two-way communication system, thus, gives the TV instructor the kind of "feedback" which is available to the classroom instructor. With it he can attempt to guide the learning behavior of his students.

However desirable this arrangement would appear to be, there are, nevertheless, logistical considerations which restrict the extent of its utility. There is undoubtedly an upper limit to the number of classes a two-way communication system can effectively link without making serious inroads on the continuity of and time available for instruction. If this is indeed the case and educational television, particularly broadcast television, cannot, therefore, reach large numbers of classrooms at the same time, one of the justifications for its use has been weakened.

If substantial inroads on time and continuity are to be avoided, there must, therefore, be restrictions on the number of questions that either instructor or students can raise. Doubts arise as to whether reduction in the number of permissible questions will permit adequate coverage of student problems. The instructor who is unaware of the range of problems students experience cannot effectively guide students in solving them. Relatively incomplete control of the learning situation will inevitably lead to student achievement which is lower than that obtained in situations where control is more extensive.

More adequate coverage of the range of student problems, both in film and television instruction is made possible by a second approach involving the use of various equipment systems (1, 2, & 16). Mechanical or electronic recording systems provide the capability of recording student responses to questions posed either during or following filmed or televised instruction. Detailed analysis of answers reveals the areas of understanding, the areas of lack of understanding, or the areas of misunderstanding. The recording procedure is adequate for purposes of sampling the range of student problems that arise in the course of a given lesson unit. But, like the two-way communication procedure, the recording of student responses for testing purposes during the lesson also destroys the continuity of instruction and diminishes the time available for additional lesson content. If questions are administered at the conclusion of a lesson, the instructor will not be able to apply corrective measures until the next instructional hour. Moreover, there is some theoretical and empirical support for the position that it is better to insure that students are capable of making correct responses than to be forced to have to correct their wrong responses.

A third approach that can offset the disadvantages inherent in instructional media which preclude teacher-pupil interaction is the "pre-testing" of lessons. During the production or pre-release phases of film preparation, student responses to achievement tests after they have seen a preliminary version of a lesson, or responses of production personnel to questionnaries, have provided useful information about the teaching adequacy of specific portions in a film (3, 6, 11, 17, 18 & 19). Results of this type of analysis can be used as a basis for revising those portions of the film which are inadequately taught.

The same methods have had an initial application to closed-circuit television instruction in a military setting (5, 8, 9, & 10). Analysis of inadequacies in ordinary lectures were used to guide the development of TV lessons; or analysis of achievement tests results obtained following a preliminary version of the TV lesson were used in the preparation of the TV lesson itself (9).

These studies have demonstrated the feasibility of using various pre-testing procedures in preparing a final version of a film or TV lesson. The pre-testing of filmed or televised lessons, it seems clear, has the potential for providing useful "feedback" to producers and instructors about the range of problems students encounter. It can, therefore, enable them to prepare an improved final product. This can be accomplished without disturbing the continuity of instruction and without reducing the time available for instruction. The modest cost of such pre-testing is more than justified when it is prorated over the large number of students who receive one TV lesson.

Purpose of the present study

This is a report of a study on an application of the pre-testing procedure to broadcast television. The study represents a step beyond the feasibility demonstrations of the past. In addition to the use of pre-test results based on a preliminary version of a lesson to prepare a final version, the study also includes an experimental comparison of the final or revised version of the lesson and the original or preliminary version which was pre-tested. The primary purpose of this study is to provide an experimental evaluation of the amount of improvement that can be brought about by the process of tryout and revision.

METHOD

An experiment was designed to measure the amount of improvement that could be brought about in a TV lesson by pre-testing it. The experiment developed to pre-test TV lessons was replicated using two different lessons, one on "the effects of heat" and one on "an introduction to chemistry." Both lessons were integral parts of an entire Junior High School science series presented throughout the school year by Metropolitan Pittsburgh Educational Television Stations (WQED-WQEX). For each of the two lessons, a competent Junior High School science teacher was assigned the task of preparing a statement of lesson objectives. To be able to do this effectively, the teacher became familiar with the entire series of instructional half hours, with what preceded each lesson and with what was to follow. Based on this familiarization and a careful delineation of how the lesson was to fit in with the entire series, lesson objectives were prepared. The teacher identified the facts the students were expected to learn and the concepts they were expected to understand.

With the collaboration of a television director, the teacher then prepared a lesson that sought to meet these objectives. The script, the visual aids, the demonstrations, and the stage business were developed and, following studio rehearsal, the lesson was recorded. The amount of time and effort devoted to all these phases did not exceed the average amount of preparation for other lessons in the entire series. Thus, the lesson obtained can be described as having undergone no special amount of preparation. (The scripts for the lesson on "heat" and on "chemistry" appear in Appendix A.)

Pre-testing of lessons

On separate occasions the lessons on "heat" and "chemistry" were given preview showings. They were shown during nonpeak hours on an UHF channel (WQEX - Channel 16) in order to insure that students who would participate later in the experiment proper would not be likely to view the preview telecasts. Each lesson was seen by a class of thirty to forty students who, in terms of ability, were representative of other students who customarily viewed the science series at its regularly scheduled time. Following the preview showing, students took an achievement test based on the lesson.

As was the case for the lesson itself, the test was designed to cover the facts and concepts listed in the statement of objectives. It was also designed to determine how adequately various parts of the lesson, particularly the demonstrations, were learned. A systematic attempt was made to have all key material in the lesson represented in the test. (The tests administered after the preview showing of the televised lessons on "heat" and "chemistry" appear in Appendix B.) Analysis of test results revealed which points appeared to be adequately understood, which points were evidently not understood, and which points were misunderstood. The research staff then reviewed test results item by item and the filmed lessons part by part in order to discover the possible reasons for the various inadequacies. This review was the basis for suggesting improved, revised methods of presentation. The TV instructor and the TV director were then briefed on how these improvements might be implemented.

In the lesson on heat, for example, a major point covered was the expansion of solids when heated. The TV instructor first passed a metal ball through a ring and then withdrew it. He repeated this several times, illustrating the ease with which it could be done. Then he passed the ball through the ring, retained it in this position, and heated it (see Figure 1).

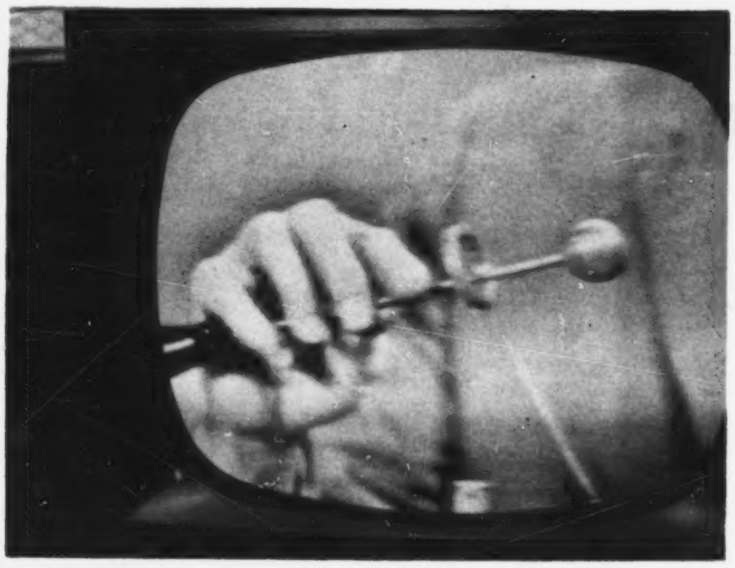


Figure 1

After the metal ball was heated, the instructor forcibly tried to remove it from the ring. The effort the instructor expended was highly visible and the resistance the ball encountered highly audible, indicating graphically the instructor's inability to remove the metal ball due to its expansion from heating. Results for specific achievement test items about this demonstration revealed that students who saw the preview showing had no difficulty understanding the principle being illustrated. No revision of this demonstration was judged necessary and none was made.

A demonstration showing the effect of heat on a bi-metal bar, however, was less successful. It was intended to show that the differing expansion coefficients for the two metals in the bi-metal bar would cause it to bend when heat was applied. To illustrate its bending properties, the bi-metal bar was used in a thermostat arrangement in which the bending bar would make an electrical contact and ring a bell. Test results showed that students misunderstood the nature of the relationship between the ringing bell and the properties of the bi-metal bar.

Part of the difficulty seemed to be that only a slight degree of bending was required for the bar to make electrical contact (see Figure 2a). This was not clearly perceived by the students. Accordingly, a change was made in the apparatus so that the bending of the bar would be more conspicuous (see Figure 2b). The verbal commentary was also improved.

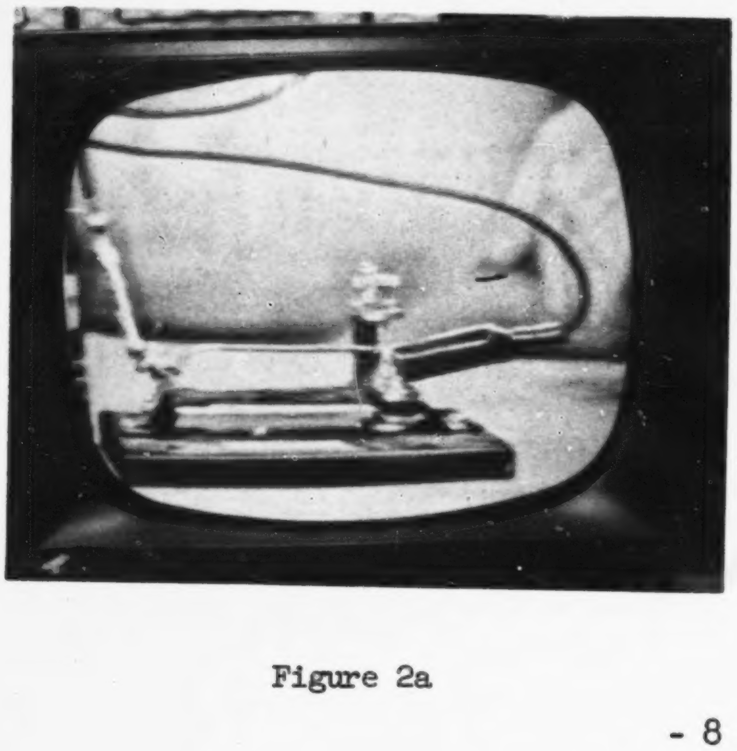


Figure 2a

Figure 2b

Similar analyses were made for other individual test items to determine how well students understood specific points in the lesson. When judged necessary, changes in both verbal material and the visual presentation were made throughout the entire lesson. This resulted in a new or revised version of the lesson which was then recorded. Thus, two versions of the same lesson were available for comparison, the original or preview version and the new, revised version.

Experimental procedure for "heat" lesson

On the day the lesson on "heat" was regularly scheduled to be shown, both versions were telecast simultaneously. One was telecast on WQEX (UHF - Channel 16) and the other on WQED (VHF - Channel 13). Six sample classes from the entire group of seventh and eighth grade classes which regularly viewed the Junior High School science series were selected to participate in the experimental comparison. Three intact classes in three different schools watched the experimental lesson (the new or revised version). Three other intact classes from three still different schools watched the control lesson (the original, preview version). Experimental and control classes were matched for grade level and for IQ to form three pairs of matched classes.

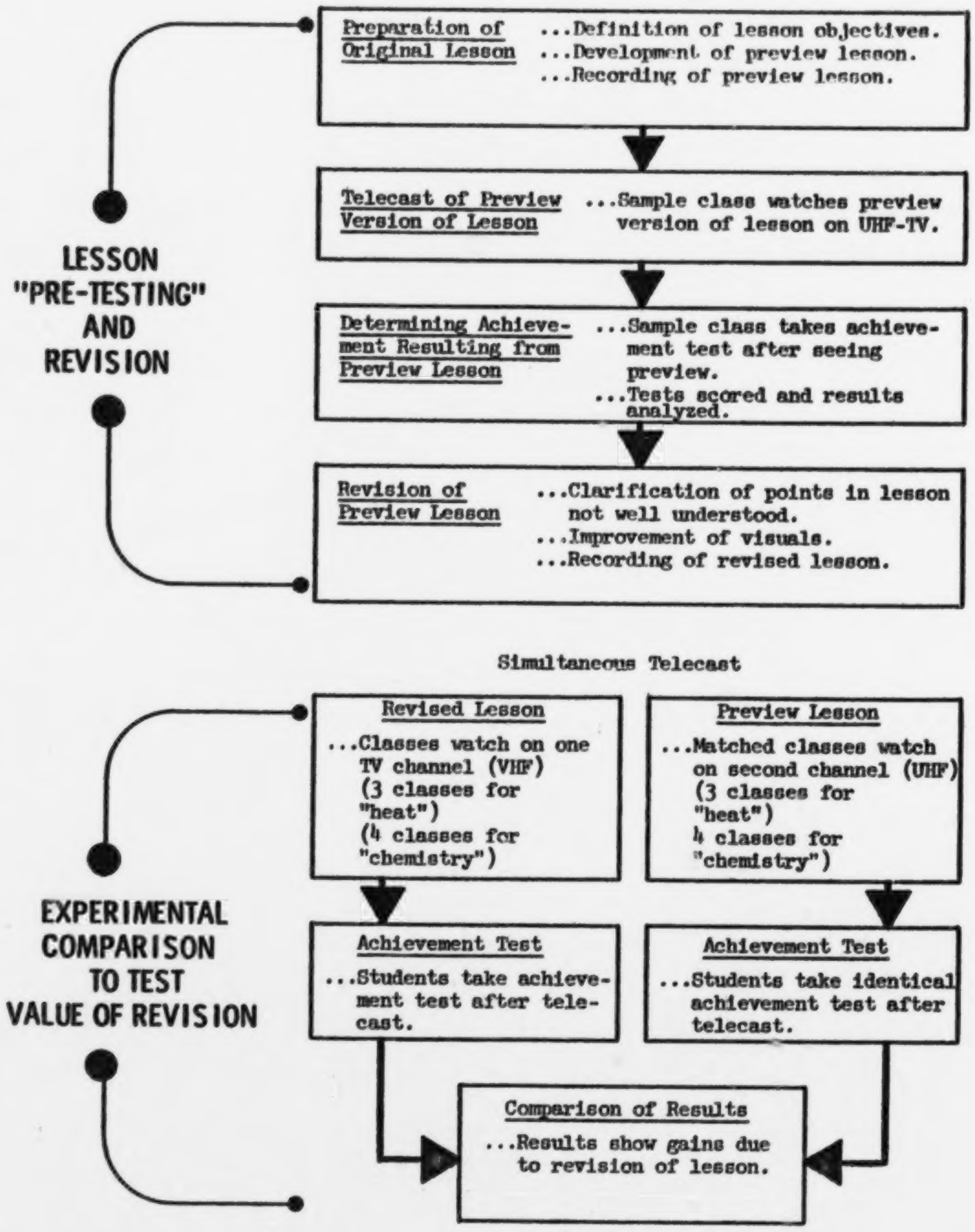
Entire classes, rather than individuals, were assigned at random to experimental and to control groups. In much "contextual" research, as in this case research within the framework of public and parochial school systems using the televised science series, it is not always administratively feasible to use individual sampling. When entire, intact classes are sampled instead, they, rather than individuals, become proper units of observation and analysis. Data collected in the comparison of experimental and control groups in this study, were accordingly statistically treated using the class rather than the individual student as the unit of observation (12).

Data consisted of scores obtained from achievement tests administered after the telecast of the lessons. The tests were designed to cover the stated objectives for the lessons. Identical tests were administered to experimental and control groups (see Appendix B).

Procedure for "chemistry" lesson

The same procedure was followed in an experimental comparison based on the lesson on "chemistry" except that four matched pairs of classes (four experimental and four control) were used. Also, a different lecturer from the one who taught the "heat" lesson appeared in both preview and revised versions. Achievement tests were similarly administered to the eight classes following the telecast (see Appendix B). Thus, the experiment using a lesson on "chemistry" replicates the experimental comparison made with the lesson on "heat."

The entire procedure for "heat" and "chemistry" lessons may be schematized as follows.


LESSON "PRE-TESTING" AND REVISION
Preparation of Original Lesson
...Definition of lesson objectives.
...Development of preview lesson.
...Recording of preview lesson.
Telecast of Preview Version of Lesson
...Sample class watches preview version of lesson on UHF-TV.
Determining Achievement Resulting from Preview Lesson
...Sample class takes achievement test after seeing preview.
...Tests scored and results analyzed.
Revision of Preview Lesson
...Clarification of points in lesson not well understood.
...Improvement of visuals.
...Recording of revised lesson.
Simultaneous Telecast
EXPERIMENTAL COMPARISON TO TEST VALUE OF REVISION
Revised Lesson
...Classes watch on one TV channel (VHF) (3 classes for "heat") (4 classes for "chemistry")
Preview Lesson
...Matched classes watch on second channel (UHF) (3 classes for "heat") 4 classes for "chemistry")
Achievement Test
...Students take achievement test after telecast.
Achievement Test
...Students take identical achievement test after telecast.
Comparison of Results
...Results show gains due to revision of lesson.

RESULTS

To determine the gains due to the revision of the preview lesson, results of an identical test administered to both experimental (revised lesson) and control (preview lesson) groups were analyzed. Differences between matched pairs of classes were computed to compare the relative effectiveness of each of the two versions of the lesson.

1. "Effects of Heat"

Objective items and essay test scores

Raw scores (number of test items correctly answered) were computed for the two forms of an achievement test (Forms A and B) administered following the simultaneous telecast of the revised (experimental) and preview (control) versions of the lesson on "the effects of heat." One of the distinctive advantages of television is the capability it offers of presenting demonstrations. Therefore, it is important to evaluate student understanding of demonstrations to determine whether television is making the most effective use of this capability. To do so a separate score was computed for items in the test in which students were asked to explain in their own words what principle was being illustrated by the various demonstrations shown during the lesson. Another separate score was computed for other information in the lesson as measured by objective test items and essay questions.

Table 1 below summarizes an analysis of the raw score results for combined objective test items and for essay questions on both Forms A and B of the achievement test.[1]

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[1] Since a uni-directional hypothesis was maintained, namely, that students watching the revised version of the lesson would excel students watching the original or preview version, a one-tail t-test for differences was performed. The degrees of freedom employed are based on the number of matched pairs of intact classes sampled and not on the number of students in these classes.

Table 1

Summary of Results for Combined Raw Scores
on Objective Test Items and Essay Questions
(Heat Lesson)

		Means of Class Means	S.D.[+]	Difference Between Means	t	D.F.	P
Form A	Revised Version	16.0	2.1				
	Preview Version	12.6	2.9				
				3.4	4.5	2	.02*
Form B	Revised Version	14.6	3.4				
	Preview Version	9.4	2.6				
				5.2	7.3	2	.01**

The maximum score possible in this part of the test for each of the two forms of the test was 30 points. Students who watched the revised version of the lesson on the average received test scores significantly higher than the scores of students who watched the original or preview version. Scores for students who watched the revised version averaged 3.4 points higher on Form A and 5.2 points higher on Form B of the test. This superiority for the experimental group watching the revised version was statistically significant at less than the five percent level on one form of the test and beyond the one percent level on the other.

Of what order of magnitude was this superiority or improvement of the revised (experimental) version over the preview (control) version? First, the amount of improvement possible was determined by subtracting the mean score for the control (preview) from the total possible score on the test. The difference between experimental and control groups was also computed. The ratio of

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[+] The standard deviations reported here are based on the distribution of means, not on the distribution of raw scores.

*statistical significance between the 5% and 1% level

**statistical significance beyond the 1% level this difference to the amount of improvement possible provided a measure of the amount of improvement obtained. The average amount of improvement obtained on Form A was 19 percent and on Form B, 26 percent. Table 1a summarizes these results.[2]

Table 1a

Summary of Analysis of Results for Objective and
Essay Items Expressed as Improvement Scores
(Heat Lesson)

	Mean Average Improvement	t	D.F.	P
Form A	19%	6.3	2	.01**
Form B	26%	5.0	2	.02*

Classes watching the experimental or revised version averaged 19 percent higher on Form A and 26 percent higher on Form B than did the matched classes who saw the original or preview version. This improvement over the results for the control or preview version was statistically significant.

Test items on principles illustrated in demonstrations

Results of test items based on demonstrations were analyzed separately. Table 2 summarizes these results.

On a test in which the maximum possible was 70 points, all students scored relatively low. The overall average was only 13 points. However, students who watched the revised version averaged 9.2 and 4.2 points higher on Forms A and B of the test than did students who watched the preview version. The results for Form A are statistically significant.

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[2] Results for each pair of matched classes provided an improvement ratio. A t-test compared the mean ratio based on all pairs vs. zero.

Table 2

Summary of Results for Raw Scores on Items about Demonstrations (Heat Lesson)

		Means of Class Means	S.D.	Difference Between Means	t	D.F.	P
Form A	Revised Version	17.5	3.4				
	Preview Version	8.3	4.5				
				9.2	7.5	2	.01**
Form B	Revised Version	14.7	3.6				
	Preview Version	10.5	5.6				
				4.2	1.3	2	.16

The same results converted to improvement scores are presented in Table 2a.

Students who watched the revised version scored 15 percent higher on Form A of the test than did the students watching the preview version. This result is statistically significant beyond the one percent level. A six percent improvement was recorded on the B form, but this was not statistically significant.

Table 2a

Summary of Analysis of Results for Demonstration Items Expressed as Improvement Scores (Heat Lesson)

	Mean Average Improvement	t	D.F.	P
Form A	15%	10.3	2	.01**
Form B	6%	1.2	2	.16

2. "Introduction to Chemistry"

Objective items and essay test scores

On a 52-point objective item and essay test, students watching the revised version of the lesson on chemistry averaged higher than did the students who watched the preview version. Results were statistically significant at beyond the five percent level. These results are summarized in Table 3.

Table 3

Summary of Results for Combined Raw Scores
on Objective Test Items and Essay Questions
(Chemistry Lesson)

		Means of Class Means	S.D.	Difference Between Means	t	D.F.	P
Form A	Revised Version	24.4	6.5				
	Preview Version	20.2	8.4				
				4.2	3.0	3	.03*
Form B	Revised Version	22.9	8.1				
	Preview Version	16.7	4.7				
				6.2	3.1	3	.03*

Expressed as improvement scores, students watching the revised version showed an improvement of 12 percent on Form A and 20 percent on Form B over the students who watched the preview version. These improvement percentages were significant beyond the five percent level. Table 3a summarizes the results of the analysis for the improvement scores.

Table 3a

Summary of Analysis of Results for Objective and
Essay Items Expressed as Improvement Scores
(Chemistry Lesson)

	Mean Average Improvement	t	D.F.	P
Form A	12%	2.8	3	.03*
Form B	20%	2.5	3	.04*

Test items on principles illustrated in demonstrations

Analysis of a 70-point test covering the principles illustrated by the various demonstrations in the lesson on chemistry revealed an average superiority of seven points for the group of students who watched the revised version of the lesson. The results were statistically significant on Form A of the test and on Form B approached the significance level of five percent set for this study (P=.06). Table 4 summarizes these findings.

Table 4

Summary of Results for Raw Scores
on Items about Demonstrations
(Chemistry Lesson)

		Means of Class Means	S.D.	Difference Between Means	t	D.F.	P
Form A	Revised Version	23.8	6.8				
	Preview Version	15.9	3.3				
				7.9	3.6	3	.02*
Form B	Revised Version	22.9	8.0				
	Preview Version	15.4	2.8				
				7.3	2.1	3	.06

Table 4a shows these results expressed as improvement scores. Similar to the findings summarized in Table 4, the improvement scored on Form A was statistically significant; the improvement scored on Form B approached significance (P=.07). The improvement for the revised version over the preview version was approximately 14 percent.

Table 4a

Summary of Analysis of Results for Demonstration
Items Expressed as Improvement Scores
(Chemistry Lesson)

	Mean Average Improvement	t	D.F.	P
Form A	15%	3.2	3	.02*
Form B	14%	2.0	3	.07

In all comparisons, the students who watched the revised version of the lessons on heat and chemistry averaged from six to twenty-six percent higher on achievement tests than did students who watched the preview version. Six out of eight comparisons were statistically significant at the five percent level or better with one additional comparison approaching the significance level of five percent set for this study (P=.07). Using raw scores only, the students in the experimental group (revised version) averaged higher than students in the control group (preview version). The experimental group averaged three to five points higher (out of a possible 30 points) on the "heat" objective test items; four to six points (out of a possible 52 points) on the "chemistry" objective test items; four to nine points (out of a possible 70 points) on the "heat" demonstration items; and approximately seven points (out of a possible 70 points) on the "chemistry" demonstration items. Six out of eight comparisons were statistically significant at the five percent level or better with one additional comparison approaching the significance level of five percent set for this study (p=.06).

All eight comparisons based on raw scores or improvement scores for the objective and essay items on both "heat" and "chemistry" lessons show significant differences favoring the revised versions. All eight comparisons for test items on demonstrations also show differences favoring the revised version. However, only four out of eight of these differences favoring the revised version are significant (with two additional differences approaching significance P=.06 and P=.07).

In summary, the results for students watching the revised version are superior to those of students who saw the preview version. This superiority was found for both "heat" and "chemistry" lessons on objective and essay items on the general content of the lesson. The superiority of the revised version over the original or preview version was slightly less conclusive in the case of test items based on demonstrations performed in the lessons.

DISCUSSION

One of the hazards of preparing new lesson material or of teaching a new group of students is the uncertainty about the adequacy or appropriateness of old and familiar instructional techniques. Will the instructional techniques that worked effectively for one subject matter work for another? Can the research findings based on one subject matter or on one audience be applied to another? More important, can prior research findings be translated for current use? How, precisely, can they be applied?

Research findings, for example, suggest that difficult material should be broken up into small learner steps or that it should be presented at a slow rate. In trying to apply these generalizations "de novo" to other lesson content judgments must be made about the difficulty level of a particular lesson, about what is a small enough step, or about what is a slow enough rate of presentation. Rational consideration of prior experience in lesson preparation can aid in making these judgments. Their validity, however, can be measured only empirically, that is, by determining how much students actually learned.

The classroom instructor can get some empirical evidence (though not usually very complete or dependable evidence) as the lesson proceeds by asking questions of his students or by noting their faces and the evidence they contain of apparent understanding. He obtains some immediate evidence about the difficulty level of his material or about the adequacy of his rate of presentation. Rarely, does the teacher systematically or completely obtain evidence of this kind, but, to some extent at least, it is available to him. Its availability enables him to correct his judgments about the adequacy of his lesson preparation.

The TV instructor, isolated from his students, cannot test his rational judgments about the adequacy of his lesson preparation. He receives no immediate empirical evidence which could prompt him to do this. Without it he cannot evaluate the difficulty students experience with the material or the relative effectiveness of different rates of presentation. He must rely solely on his prior experience with similar lessons and with similar student audiences. For optimal instruction this is not good enough. Ironically, the feedback to the instructor is least where it is needed most -- in TV lessons presented to hundreds or thousands of students.

Pre-testing a preview version of a lesson in this study provided the TV instructor with needed information about the effectiveness of his lesson. Relative student performance on specific items in an achievement test administered following the preview of the lesson indicated which parts of the lesson were too difficult for students to learn or understand. This empirical evidence based on the lesson content in question and on the performance of a given audience (in this case seventh and eighth grade students) enabled the TV instructor to prepare a revised and improved version of the lesson.

The worthwhileness of the pre-test and revision procedure is indicated by the fact that the over-all results show general superiority for the revised versions of both the lesson on "heat" and the lesson on "chemistry." The replication of the experiment using different lesson content, different instructors, and a different sample of classes from the same population of classes, suggests the case for general application of the lesson pre-testing method to other lesson content. The particular advantage of this technique is the use of a sample audience resembling the ultimate audience in all important details (such as age and intelligence) for pre-testing purposes. The lesson can thus be tailored for a specific audience.

With the use of the lesson pre-testing method, the absence of student-instructor interaction is no longer a primary handicap. The TV instructor can foresee student misunderstanding and forestall it as well as build student understanding. He can explicitly and systematically chart the path the student should follow in acquiring new knowledge. The limitations in the resulting presentation after successive revision should be only those inherent in the lecture method of presentation itself (whether used in the classroom or on TV). Subsequent reports in this series will discuss the nature of the general limitation in lecture presentation (whether "live" or via TV).

The generally low achievement test results for the section of the test covering demonstrations used in the lessons suggest the special need for research on science demonstrations. Particular attention should be paid to the selection of demonstrations that are used to illustrate principles and to the verbal commentary that accompanies the demonstrations. Research should focus on how to integrate verbal material and demonstrations. The results of this study quite vividly portray (even with lesson revision) that much improvement is needed in aiding students to understand the principles illustrated in demonstrations.

The method of tryout and revision holds considerable promise for the preparation of effective TV lessons. In cumulative stages and with refinements in technique, more substantial gains than those reported here should be possible. The method, moreover, enables the teacher or practitioner to determine whether he has effectively put to use research findings on instruction which often require translation to specific cases. Lesson pre-testing indicates how good the translation is.

The key features of the procedure of tryout and revision for TV instruction appear to be these: (a) the explicit specification of lesson objectives including facts and concepts students are expected to acquire; (b) the development both of lesson content and of achievement test items covering specific points in the lesson objectives; (c) the tryout over television of the prepared lesson with a sample audience from the population of classes that will ultimately be exposed to the lesson (it would appear to be preferable to try it out on TV or on film over trying it out before a live audience, as this samples the conditions including the use of visual demonstrations under which students will ultimately be expected to learn); (d) the administration and analysis of the achievement test following the preview showing of the lesson; (e) discussion with the instructor and TV production personnel of specific points in the lesson inadequately taught and of student misconceptions which could be forestalled (the nature of student misunderstanding, as revealed through analysis of incorrect test options most frequently endorsed, aids in the reconstruction of specific parts of the lesson to forestall misunderstanding; item analysis may also suggest the nature of changes in presentation that can also maximize student understanding); (f) the lesson is revised in the light of this analysis and shown on the air at its regularly scheduled date.

These were the procedures followed in this study. Their use produced substantial gains in student understanding. Such gains can be materially increased with additional stages of pre-test and revision. The number of students to be taught and the number of years lessons will be used are, of course, factors to consider in determining how much money and effort should be devoted to successive stages of tryout and revision. Each stage of tryout and revision should offer the potentiality of a substantial increase in student learning and understanding.

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APPENDIX A

Lecture Materials

1. Scripts on "The Effects of Heat"
    a. experimental lesson pp. A- 2 - A- 6
    b. control lesson pp. A- 7 - A-11

2. Scripts on "Introduction to Chemistry"
    a. experimental lesson pp. A-12 - A-16
    b. control lesson pp. A-17 - A-20

Script for Experimental Lesson

Certainly there is a lot more heat in this cup of boiling hot chocolate than there would be found in this glass of ice cold root beer. What is heat? What makes one thing hot and something else cold? The answer to that question is found by looking into the molecules of the substance that makes up the root beer, the hot chocolate or whatever else we are talking about.

Suppose we have a small drop of any substance. Let's take a drop of water for example. We look at that drop of water. We find it very much enlarged, in fact, it's enlarged so much we can see the individual molecules. Now we notice that these molecules are moving. Now this is just a drop of water at room temperature that you might call a cool drop of water. As we heat this drop of water by putting a flame near it or warming the surface it's on, we find that the movement of these molecules increases. Becomes faster and faster. So we could say that the heat is really increasing molecular motion, that heat causes molecules to move faster. Of course, within that drop of water there is constant motion; whether it is hot or cold that drop of water keeps moving all the time.

So, today we're going to talk about the effect that heat has. One effect that we're going to talk about is that heat causes expansion. Expansion means for something to grow larger. Now the first of the states in which matter exists that we're going to investigate today is solids. Solids. Do they grow larger when they are heated? Well, perhaps the best way to do that is to take a solid and heat it. However, if we heated most solids, boys and girls, we would find that we couldn't see any difference in their size. Now here we have a ball of brass, that just fits through a brass ring. Just barely makes it. If this ball were just a little bit larger we couldn't get it through the ring. So we're going to insert the ball first of all through the ring. Now we're going to light our bunsen burner. Now we're going to heat one of these. We're just going to heat the ball, the ring is staying back here away from the heat where it's cool. We're heating the brass ball, it's about 3/4 of an inch in diameter. Now what's going to happen inside this brass ball? The heat will increase the movement of the molecules. The molecules will move around faster and faster and the ball will grow a little bit larger. Not much mind you, not enough that you can see it. Some of the things we are going to heat today you'll be able to see them move and expand easily. But you can't see this grow any larger but we can test it now by trying to pull it through the ring. And it will just not go through. That ball is large enough now that it will not pass through the ring. Now let's try the opposite of heat. Let's try contraction and see what happens. And that means slowing down the molecules or cooling the object. We take away some of the heat. Now when the heat is taken away, the size is reduced so it will now pass through the ring. Cooling it slows down the motion of the molecules and reduces the size of it. So we can say that when a solid is heated it expands. This is true for something that is a round shape or something of a different shape.

Here we have a piece of copper wire. I've stretched it between these two upright posts. We have a small weight in the center of it. Now behind the weight I've added a little marker so you can tell where the weight was at the beginning. Now we're going to pass electric current through this wire. Notice what happens when we heat the wire just a little bit. Did you see the wire drop down? Then as it cools off, it comes back up slowly. Let's try that again. By heating the wire we were able to make the wire expand. But this wire is so set up because of these two poles that it can't expand that way. So when it grows a little bit longer the only thing left for it to do is sag in the middle. Gravity pulls the weight down to show us this wire has become longer. It has been heated. The heating has made the molecules move faster and when the molecules move faster it expands, when it expands, the wire sags down. And so, the heat causes the molecules to move fast which causes the object to expand. We certainly explored solids, and we know solids expand when heated but what about liquids?

Now let's try an experiment with liquids. Here is the liquid we are going to use. Probably the most common liquid in the world, water. Just plain, ordinary water. To describe the piece of equipment we have here, we have a flask with a one hole stopper and a glass tube. Now when we push the stopper into the flask of water, you'll notice what happened, the water went half way up the tube. This much is still air space. Now we're going to heat this flask of water again with the bunsen burner. Notice what's happening to the water, it's going up the tube. The molecules are moving faster, the water has to expand and since the glass won't let it expand sideways, there is only one place for the water to go and that's up the tube. By continuing to heat it, we can run the water right out the top of the tube. Heat also causes liquids to expand. Now water, we're going to come back to water a few minutes from now and I'll tell you some interesting facts about water at certain temperatures, but generally speaking at room temperature, at any common temperature, water expands when it freezes.

The most interesting of all of these because this happens the most rapidly, is if we try several experiments with gases to see if gases will expand when they are heated. We found that solids when they are heated expanded a little bit, enough that the ball wouldn't go through the ring. But you and I couldn't see it expand. In liquids we were able to see the liquid go up the tube when it expanded. Now, I think you'll like this, because with gases it expands even more. First of all, let's begin with an empty flask. Now an empty flask contains nothing but air and we've attached a balloon here to the end of it, just an ordinary kid's toy balloon. And we're going to heat just the flask so that you can see what happens to the air in the flask. Heating the flask now watch the balloon here. And the more you heat it the more the air expands. The air has pushed out and expanded and the balloon is inflated. Where does this air come from? Is there any way for air to get into this? The answer is no. The air is already in here to begin with. It is now a little bit warmer and it has expanded.

Here we have an air thermometer. This one has become filled with water. Could we have another one and we'll come back to this one in just a minute. Water has been drawn up into this one. We'll start again with another one. In the meantime, we have another experiment on the same thing. The expansion of gas. This is called a pulse glass. It was invented by, of all people, Ben Franklin. Now this pulse glass contains alcohol and a gas above it. A vapor of alcohol; there is no air in it. Now at first you might think he is going to be heating the liquid. That's not true. I'm just going to warm the air that is above this liquid and you can watch what happens. We heat the air above the liquid, the air presses down on the liquid and first of all the liquid runs over to the other side. Then we can turn this around. Now, again I'll heat the air above this liquid, just the warmth of my hand makes this work, showing that certainly gases react to heat far faster than liquids or solids do because the heat of my hand wouldn't do anything with the ball and ring and the heat of my hand wouldn't drive the water up the tube.

Now we have another air thermometer here and we're going to try this again. This is just a glass globe completely empty filled with air. The glass tube comes down into the beaker of water. Now we're going to heat the air inside this glass globe. The air is going to expand and you'll see it come bubbling up out of the bottle. See those bubbles rising there? This is because the air inside this glass ball is expanding and the bubbles of air come out the ball. So, we've had three experiments with gases and two of them we've used ordinary air and the third one we used a vapor of alcohol and we've shown that very definitely expansion takes place in solids, liquids, and gases. Solids don't expand as much as liquids and liquids don't expand as much as gases, gases expand the most rapidly and react the fastest.

Now within any of these classes, let's take solids for instance, let's take two different solids steel and copper for instance, or you could take any other two solids in this world, and they probably have their own rate of expansion. In other words, different things expand different amounts. This is a bi-metal bar. A bar made of copper on this side and steel on this side. We're going to use the bunsen burner and heat this bi-metal bar. And you can see what happens very definitely. It bends. Now the copper is on the outside of the bend always because the copper expands so much more than the steel does. We have a tall beaker of water that we can put this in and that straightens it right out for us. Then we can heat it up again, this time let's turn it around so the steel is nearer the flame and repeat the same experiment. The steel is nearer the flame, I guess that's the way we did it the last time. Now let's try it the other way with the copper nearer the flame. And you see, it doesn't depend on what side I'm heating. This bar bends because copper on the outside expands so much faster than steel on the inside. Copper expands much more than steel does. And this is called a bi-metal bar.

Well, you might say that's a very nice laboratory curiosity but what good's it going to do me? Well the truth is, you use this, or this helps you at least, every day. Because this bi-metal bar that we have here is the same type of a bar that is used in a thermostat. Now, this is certainly not the thermostat that's on the wall of your dining room. I think they look quite different. We have attached two other things to this thermostat. I'd like to show you the whole piece of equipment; first of all, a bell, a door bell, an electric door bell, which sounds like that, a battery which is our supply of current, and of course, the thermostat. Now the thermostat is so wired up that when I bend this bar down with my finger, and I'm just going to take my finger and press this bar down, you can see that it makes contact and the bell rings. Now instead of pushing it with my finger we know that a bi-metal bar, and that's what this is, a bi-metal bar, when heated, and for heat we just need the flame of a match, we'll add a match flame underneath it, can you see it bending down there? It comes down and down and finally it rings. Now I remove the heat, the flame is away from the metal, and the bar is rising. We will try it again with heat from this match and so it comes back up. The heat caused the bi-metal bar to bend, when it went down it made an electrical contact, which in this case, rang the bell. Now I'm sure you can think of how it works in your home. The thermostat in your dining room, or wherever it's located in your home, continually watches the temperature of your house. When your house becomes too cool, it comes up, in this case it relaxes, comes up when it's too cool, makes contact and turns on the furnance. When the furnance has heated your home warm enough, it comes and separates it. It works exactly like this laboratory model only I hope yours looks a lot nicer on your dining room wall than this laboratory model.

Now we said that everything has its own rate of expansion. Copper and steel expand at different temperatures and of course its rate of expansion is what makes the mercury or alcohol in a thermometer go up or down. And, we're continually asked, couldn't you make a thermometer out of water, use water? The answer to that is very definitely no. Water has a very peculiar characteristic. Suppose you have a beaker of water here, and you start cooling it. It contracts and contracts and would work very well in a thermometer; it would come down and down, but just before it got to its freezing point, the water would expand again. In other words, just before water freezes, it's sort of an exception to our rule, instead of continuing to contract it expands.

Now there is a product here that I think is very nice to use in classrooms. The inside of this beaker is more than 50 degrees below zero. That's so cold in there it would freeze anything that was put into it. This is a small bottle, a small asprin bottle of some kind, that is filled with water, filled right to the top. We're going to lower this down into the freezing mixture. Let me explain how this freezing mixture is made, so in case you might want to use it in your classroom. It's a mixture of dry ice and alcohol. To help to keep too much heat from the room from going into this, we have this in a pair of beakers, one set inside the other. Then we add a little lid on top of it for awhile. But this mixture of alcohol and dry ice gives you a very low temperature. Any time your experimenting in your classroom and you want a very low temperature, try mixing dry ice and alcohol. Don't ever put your fingers in here because it's really cold.

Let's see if we can find out bottle of water and we can show you, now, very plainly why you wouldn't ever use water for a thermometer. The reason is that the glass, as it froze, and this bottle is completely frozen, the glass is all broken. It has expanded and cracked the glass on this bottle. Now you can do the same thing by putting a bottle of water outside on a very cold day. We're going to set it in some hot water here, this won't crack the glass, it will just melt the ice and maybe you can see then what has happened to our bottle. The bottle was broken not by being put in the hot water but by the freezing of the ice. You get a real cold day this winter and you might try this. Just take a small bottle of water, put a cap on it, let it freeze and you'll find that water is sort of an exception to the rule that things contract as they get cold, because just before water freezes it expands. That force of expansion could break a bottle, in fact, it can actually break cement or steel.

Now we have been talking about the effects of heat. One big effect of heat is expansion. Of course, it is my hope that you have understood that the taking away of heat causes the opposite which is contraction. But, heat causes expansion in solids, liquids, and gases. Now there is another big effect of heat, and that is that heat causes a change of state. Now you know the states in which matter exists; solids, liquids, and gases. And heat can cause a solid to change to a liquid and a liquid to change to a gas. We're going to show you that in just a minute and then we're going to show you the exact opposite. We're going to show you a gas changing into a liquid and a liquid changing into a solid. The second big effect of heat is change of state.

To begin with, we're going to use this test tube which contains a little bit of ice. Three small pieces of ice. I think you all know that's H_2O in its solid form. We're going to use the test tube clamp and since it's in a solid state we can lay it down without danger of it running out. We have the solid form here, ice. Now we're going to heat it and as we heat this we're adding heat to this solid and it's becoming not a solid but a liquid. Here we have a solid changed into a liquid and the only way we did this was by adding heat. Now let's continue to add heat to this liquid and watch what happens. Very quickly you can see it's going to change into a gas. The gas that we call steam. So we can change a solid into a liquid and then into a gas just by adding heat.

Now let's talk about that gas that we formed, steam. It's going to be coming out of this elbow up here. Already you can see it clouding up this part of our condenser. A condenser is something that takes away heat so we're going to take away heat from the steam and it turns into a liquid. Now if we look down at the far end of our device we can find this liquid dropping into the small test tube. We're changing a gas back into a liquid and then we can take these few drops of liquid and very quickly put them into our freezing mixture and cause them to freeze into the solid state. In others, adding heat to a solid can change it to a liquid. Adding heat to the liquid can change it to a gas. Heat causes a change of state.

Now the absence of heat causes the reverse thing to take place. We stated with the gas, steam, we used this condensor to take away some of its heat and we got a liquid. The liquid that we call water. Then we captured this liquid in a test tube, put it in our freezing mixture which took away even more of its heat, and taking away the heat it formed into this little white solid, ice, at the end of our test tube. So we can go from gas to liquid to solids by taking away heat.

This is the beginning of our unit on heat. We're going to spend about five more lessons talking about other things that heat does but it's very important that you understand that heat causes the molecules in any object to move faster and faster. Whether it's a solid, liquid, or gas heat causes expansion. Then, a lot of heat added to a solid can change some solids into liquids and even more heat can change it into a gas. In other words, if you heat up the motion so fast that this ice no longer is a solid but its molecules are moving so rapidly that it becomes a liquid and then you speed it up even faster and it becomes a gas. Two big effects of heat are expansion and its opposite, contraction, and change of state, going from solids to liquids to gases or from gases to liquids to solids.

Now, in tomorrow's lesson we're going to tell you something about the instruments that measure heat, about thermometers and I think you'll see some thermometers of the kind which you have never seen before.

Script for Control Lesson

What is heat? This cup of boiling hot coffee and this glass of ice cold root beer are certainly quite different as far as heat is concerned. Just what makes one thing hot and another thing cold? What do hot and cold really mean? Well, if you could imagine looking at a drop of water as it sits on a surface of a table, a side view of this drop of water, if it were magnified many, many times, large enough even that perhaps you could see the molecules of water that make up that drop of water, and of course, you and I know there are billions of molecules in a drop of water. Well, these molecules are in constant motion. And in rather cool water the objects move back and forth, the molecules move in a drop of water, even though that drop of water may seem to be very slow and very still as it sits there on the table before you, within it there is a lot of motion. And then as you heat that drop of water, the movement of the molecules becomes faster and faster and the molecules move rapidly around in the drop of water. Now that is what happens, as far as the molecules are concerned, when you heat a drop of water. And today, we want to discuss just what happens when you heat something. In other words, boys and girls, what are the effects of heat? Well, one effect of heat, the first one we're going to talk about today, is expansion. Expansion means to grow a little bit larger. Why do things grow larger? The reason, of course, being that molecular motion requires more space. For instance, take your own class. Whenever you are doing something that is quite still, something that requires very little motion, such as a reading lesson, you know that the 36 of you, or however many there are in your class, can sit quite still in the confines of a small classroom. However, if you are having an active play period, such as a gym class or a ball game of some kind, you move around and you need far more space. Well, that's just the way it is with the molecules. This metal ball, of course, has millions and millions of molecules in it. Now, its size is so that it will just pass through this ring, just barely pass through the ring. But it will pass through the ring. Now we're not going to do anything to this ring, we're going to keep it the same size it is right now. But we are going to do something to the ball. First of all, we have to light our bunsen burner and then we're going to place only the ball of our apparatus in the flame. And we're going to heat it. Now, while its being heated, boys and girls, something is happening in there to the molecules. They were moving even at room temperature, but as we heat it up to three or four hundred degrees, they will move even faster. Just as when you boys and girls move faster, you need more room for your activities, this ball is going to grow a little bit larger. Only you're going to say, Mr. Shaffer I can't see it growing any larger, it looks the same size now as it did when you started. Well, the way to test it, of course, is to pass the ring back over it. We'll take it out of the flame now and pull the ring up and see if it's hot enough. And that ball has grown so large that we cannot get the ball to pass through the ring. It has expanded. The heat has expanded it so it will not fit through the ring. Now we can reduce its size, cool it by plunging it in a beaker of water and it passes through again very easily. And so you see one thing that heat has done. It causes this solid ball to expand. And that's true of most solids. Heat will cause most solids to expand.

Here we have a copper wire. A very thin cooper wire with a weight hanging on it. We placed this scale behind it so that you can find a reference point to see just how high up in the air this weight and wire are. Now we're going to heat this wire. We could do it by running a bunsen burner across in front of it, but we're going to do it another way. We have a large storage battery here that puts out 12 volts at high amperage and we're going to connect this storage battery through these rather heavy wires on to this thin copper wire. This wire is going to become hot, it will probably become even red hot, the insulation on it may even smoke and burn. But the important thing to watch is what happens to this weight when this wire becomes red hot. Now we'll connect it. And you saw what happened. The weight went down. Disconnecting it, and watch what happens, the weight comes up a little bit. Reconnecting it again, it falls, allowing it to cool, it rises. Now just what happened? The fact is that this piece of wire expanded when it became hot. The molecular action became so rapid that the wire had to become a little bit larger and so it couldn't expand out this way because it's held by two rigid iron poles that are fastened securely on our table top. And so, it became longer and sagged down and then when it was allowed to cool again it came back to its normal position. Heating this piece of metal made the molecules move faster and what happened when the molecules moved faster? This solid copper wire expanded. Heat can make solids expand.

But I wonder what about other things. I wonder what about liquids and gases. Can heat make a liquid expand? Well, let's add liquid to our list and then let's try an experiment. Here we have a flask that's been filled with water, just ordinary water, and this water has had some dye added so that you can see it. There's a rubber stopper in the flask and the water is up about that high in the tube at the present time. Now if we heat this flask of water, heat it rather gently with our flame, and the water was less than halfway up the tube, this will act just as, well I think you can think of a very common scientific tool that you probably have in your home, just as a thermometer does. When you heat the alcohol in a thermometer or when you heat the mercury in a silver colored thermometer, you will notice that it does go up. And that's what is happening here. Already the liquid is two-thirds of the way up. What we're really doing, boys and girls, is increasing the molecular action in this water. We're adding heat, the energy of heat, that energy of heat is speeding up the molecules, the molecules are moving faster, they have to expand, there's nowhere else to go except up through our glass tube. And that's why heating a liquid will make it expand.

Now the third class that matter exists in, I'm sure you all know, say it, solids, liquids, and you say it, that's right, gases. Solids, liquids, and gases expand when they are heated. Well let's try three different demonstrations to show that solids, liquids, and gases do expand when they are heated. Here we have a flask of air mostly. Now it contains a very little bit of water at the bottom. This water also has some color added so that you can see the water when it goes up in the tube. However, this is mostly a flask of air. Just air with a little bit of liquid at the bottom. Now to heat this, gases react so quickly that I don't need to use the large bunsen burner for this. Just the warmth of my hands will expand the gases in this flask, push down on the water, the water will rise up the tube to show you the gas in here is expanding. Now I'm just heating it with my hands around it and you can see the water will rise up, actually it will rise out the top and flow over if we hold it on long enough. There it is about a half inch from the top and there it's actually ready to come out the top, so I'd better stop. Gases when they are heated will expand. And when they expand, in this case, they were pressing water out. It may be a little bit easier for you to see it happen if we take something that has no water associated with it.

This is a completely empty glass ball, glass sphere, and we're going to put this glass sphere into a beaker of water. The only reason we are using water is that if I would just heat this this way, the air would come out the bottom and you couldn't see anything. I'm going to heat it by putting the flame near it and you watch closely at the bottom end and see if you can detect bubbles of air. Of course, they are not hard to see. There is quite a flow of air bubbles out of there. The reason is, of course, because the air in here was expanding and gases expand when they are heated just the way liquids and solids expand when they are heated.

We should point out that most solids expand when heated, most liquids expand when heated, and most gases expand when heated. There are some exceptions and we'll get to those in just a moment.

Here is a rather interesting device. I think the history of this is probably as curious as the device itself. It is called a pulse glass; nothing more than two large glass flasks connected together, the air is withdrawn from these and alcohol has been put in. The alcohol has been colored so that you can see it. We're going to heat the gas in the top part of this dome with our hands. This will expand and if all works well, push the liquid up into the second sphere and if it works well enough, actually cause bubbling in this sphere that will look like it's boiling. What is really happening is that the gas is expanding and will push all of this liquid up and into this tube. Let's try it now. Just using the warmth of my hand, the liquid transfers up into the front globe. The interesting thing of this, of course, is who invented it. It was invented here in America quite some time ago by Benjamin Franklin. This is a model of Benjamin Franklin's pulse glass.

We have driven all the liquid over into that tube and we continue to heat the alcohol fumes that are in this rear globe and you can see the bubbling and the apparent boiling that takes place. Actually what we are doing is using the warmth of our hands to expand the gas and drive it up into the front chamber. To save time, we just turn it around and heat the back of it now and the same thing can be repeated in the opposite direction. It is just the energy of heat from my hand, driving this liquid from one into the other, proving again that heat does cause gases to expand.

We have shown you that solids, liquids and gases expand when they are heated. Solids, liquids and gases expand when heated. Everytime I say that I should use the word "most". Most solids, liquids and gases expand when heated.

Did you ever see a thermometer that used colored water rather than mercury of alcohol? Well, the answer to that is that I don't believe you have. I don't believe you ever have seen water used in a thermometer. We're going to show you in a few minutes why they don't use water.

Something else that is true of solids, liquids and gases is that they expand at different rates. For instance, you say that the water didn't expand nearly as fast as the gas. I could drive the water up the tube in the gas with just the heat from my hand, but I had to use the bunsen burner to drive the liquid up the tube. That is true of almost everything. Everything has its own rate of expansion.

Here is a bar of steel and a bar of copper that have been welded together. Let's watch what happens when we heat this bar of copper and the bar of steel. You see it bends and goes back. When we cool it, while it is cooling just even here in the air, it tends to straighten out. Some people say that is because I was heating this side of it. Watch, we'll heat the inside of it and it curves even more. There we have a three-quarter circle. This expands because copper, or bends in this direction, because copper expands more than steel does. We can make use of this scientific principle of a bi-metal bar. That is called a bi-metal bar when it bends that way. We can make use of this in such things as the thermostat used in your home.

Here we have a thermostat that has been connected to a battery and a bell. This bi-metal bar comes across and I can make this bell ring. By pressing down on this bar, we can make the electrical contact close in here and make the bell ring. I'll just press down with my finger and the bell rings quite loudly. But now let's try another way of bending that bar. Just the heat from a match, actually it takes very little heat to do this, will bend this bar down and when it is hot enough, it will ring. As it cools it comes back up. This is a bi-metal bar of the type that is used in a thermostat. When it is hot ... then it stops again. A bi-metal bar made of steel on the one side, brass on the other side, when heated, bends down to make an electrical contact and, of course, we can use that contact to heat your home, operate air-conditioners. This can be used any place where a thermostat is used. Also, in a lot of thermometers, the type of thermometer that has a pointer in it, uses a bi-metal bar because things expand at different rates.

We said earlier that most things expand when heated and we asked you why you never saw a thermometer that used colored water. The reason is that something is going to happen to this water when we freeze it. We have a very small glass bottle with a screw cap on it and it has been filled with just ordinary water. We'll place this in our beaker. This beaker contains a very nice mixture that can be used in your classrooms if you ever want real cold temperatures. This is a mixture of alcohol and dry ice. Alcohol and dry ice, when mixed together, will give you a temperature of 50° below zero fahrenheit. That is really cold, 50° below zero on a fahrenheit scale and sometimes you can get it much lower than that. We're going to come back to this in a minute and you'll see what has happened to this bottle of water. Normally, you would say that as it cools, it contracts, but that is not quite true with water.

This is an ice bomb, a device put out by science supply houses. It is an awful looking thing, I must confess. You fill it with water and when it is completely full of water, you put in the screw cap, tighten it with a wrench so that the water cannot go anywhere. Then you leave it outside on a freezing day, a day that has a temperature below freezing, say 20° fahrenheit. What will happen is that the freezing force of the water, just as is going to happen to this bottle, will crack it. The freezing will split this heavy piece of cast iron.

We'll go back to that in a moment, if we have time, but there is probably another effect of heat that is very important. That is that heat, either adding it or taking it away, can cause a change of state. Things exist as solids, liquids and gases and heat can actually cause one of these to change to this. The easiest way to see that perhaps, is with a small piece of ice. We'll pour out any water that might be in this. Now we'll heat it. This water is in its solid form. By adding heat to this, changes what was a solid a moment ago, to a liquid. Then we can keep adding more heat and the liquid will go from being a liquid into steam. You can see the water vapor to show that we are using steam.

What we have done here is to make the solid change to a liquid by adding heat. To make the liquid change into a gas, we added heat. Now, we can do the same thing in the reverse direction by attaching this test tube to a condenser. We're going to boil this liquid and start with steam. Just forget about the original test tube here and let's start just talking about steam, at this point here. Here it is in a gas state and we have a condenser here that will take the heat away from the gas and then the gas will change into a liquid. Then we can use this test tube and down at the bottom, we can use this small test tube. Here comes our first drop of water, changing a gas back into a liquid. Then, of course, we can add this liquid to the freezing mixture that we have over here and freeze it back into ice. The bottle that we have put in there is split and broken. I don't know if you'll be able to see it or not. The reason it is not falling apart is because of the many pieces of ice that are holding the pieces of glass together.

Going back to this demonstration, the steam had heat taken away from it and became a liquid, then we have the liquid here and we take heat away from this liquid and it changes back into a solid. So, we can change something from solid to liquid to gas by adding heat and we can change something from gas, the steam, to liquid, the water, to ice by taking away heat. This is now frozen into a little block of ice.

So, we have two big effects of heat, expansion and change of state. Heat can cause most solids, most liquids, and most gases to expand. It can also cause a change of state. It can cause matter to go from solids to liquids to gas.

In tomorrow's lesson we'll go on with thermometers and instruments that measure heat. After all, it is important to know when you say something is hot, just how hot it is. So, tomorrow's lesson will be on thermometers and the measurement of heat.

Script for Experimental Lesson

What you see now is common table salt being poured into a dish. What is it made of?

My name if Mr. Lee. Today we're going to talk about what matter is made of. Salt, sugar, and iron are examples of matter. What are they made of?

This is the problem that the science of chemistry deals with. Chemistry deals with the composition of matter and the changes in composition that matter undergoes. Chemistry studies what matter is composed of and how the composition of matter changes.

Let's start at the beginning. What is matter? Matter is anything that has weight and that occupies space. Matter is anything that has weight and occupies space. In addition to having weight and occupying space, matter can be divided into smaller parts.

Matter is made up of different combinations of elements. For example, salt is made up of the element sodium and the element chlorine, and salt is often referred to as sodium chloride. This is a table showing all the elements of which matter can be composed. Each element is represented on the table by a letter or symbol. Here is the symbol Na for sodium. Here is Cl for chlorine. Here is H for hydrogen. Here is O for oxygen.

Scientists use symbols as a shorthand way of representing the various elements. Scientists all over the world use the same symbols and can understand each other. Each element has its own symbol. Scientists have discovered 92 elements that are found in nature. These first 92 elements on the table are found in nature. The elements from 93 to 103 have been made by man. These last 11 elements from number 93 to number 103 are not found in nature.

Let's go back to our example, a substance or compound like salt. Salt is a *compound*. This means it is a combination of two different elements sodium and chlorine. These elements are combined into a single *molecule* of salt. Each and every grain of salt can be broken down into thousands of tiny parts called molecules. M-O-L-E-C-U-L-E-S. Molecules are so tiny that even with one of our most powerful microscopes, the electron microscope, we cannot see them. Yet, even in one grain of salt there are thousands and thousands of molecules of salt.

We can break up a substance or compound like salt into its molecules. A molecule of salt is the smallest particle that we can break salt up into and still have the properties of salt. Salt is whitish and has a salty taste. If we could see and taste a molecule of salt it would *also* be whitish and taste salty.

Even though we broke salt up into tiny particles, which we called molecules, these tiny particles would still retain all the properties of salt, such as whiteness and saltiness.

However, if we break down the molecule of salt into *still* smaller parts we will *no longer* have the properties of salt such as whiteness and saltiness.

What are the particles that are even smaller than molecules? Molecules can be broken down into *atoms* which are even smaller. The word atom was first used by a Greek philosopher, Democritus, about 400 B.C. Democritus stated that all matter is composed of small particles called atoms.

When the molecule of salt is broken down into atoms we no longer have salt or any of its properties such as whiteness or a salty taste. The molecule of salt is made up of an atom of the element sodium and an atom of the element chlorine. We have an atom of the element sodium and an atom of the element chlorine which have their own properties. These properties are different from the properties that the molecule of salt has. If we could see or taste an atom of the element sodium or of the element chlorine neither would be white or taste salty.

Let's represent the molecule of salt by this tinker toy. This molecule of salt has all the properties of salt such as whiteness and saltiness.

The molecule of salt in turn is made up of the two smaller particles or atoms; an atom of sodium and an atom of chlorine. If we break up this molecule of salt we end up with an atom of the element sodium and an atom of the element chlorine. Remember, Na is the chemist's shorthand symbol for sodium and Cl is the chemist's shorthand symbol for chlorine.

Here we have the atom of sodium. The atom of sodium doesn't have the properties of salt. It has its own properties. For example, sodium is a brownish gray solid and it's not like salt at all. Sodium left out in the air will burst into flames.

Here we have an atom of chlorine. The atom of chlorine doesn't have the properties of salt. It has its own properties. Chlorine in this bottle is a light greenish gas that has a foul odor.

Thus the atoms of the elements sodium and chlorine have their own properties which are different from the properties of salt which is described as being white and salty.

If we put the atom of sodium and the atom of chlorine back together again, we get a molecule of salt. The molecule of salt now has the properties of salt again.

The molecule of salt or the molecule of any substance or compound is thus the smallest particle that has all the properties of that substance or compound.

We saw that molecules can be broken down into smaller parts called atoms. We talked about the atom of the element sodium and about the atom of the element chlorine. The atom of sodium has all the properties of the element sodium. All the atoms are alike and each atom of sodium has all the properties of sodium.

The atom of chlorine has all the properties of the element chlorine. All the atoms of the element chlorine are alike and each atom of chlorine has all the properties of chlorine.

The atom of any element whether it's sodium, chlorine, hydrogen, oxygen, or any other element, is the smallest part of the element which has all the properties of that element.

If we were to break the atom up into smaller particles we would no longer have the properties of the element. The atom is the smallest particle which retains the properties of the element.

But atoms can be broken down into smaller parts. What are these parts? The principal parts of an atom are: the electron, the proton, and the neutron.

This illustration represents the structure of an atom. We have electrons circling a nucleus which is made up of two parts: protons and neutrons. The circling electrons have a negative electrical charge. The nucleus in the center is made up of protons and neutrons.

The protons have a positive electrical charge and the neutrons have no charge at all. Thus we have electrons with a negative electrical charge circling a nucleus made up of protons with a positive charge and neutrons with no charge.

We can now show you how all these elements that we talked about before are made up of atoms which have a certain kind of atomic structure. Each element is made up of an atom that has its own weight and its own structure.

We can think of an "atomic ladder", starting at the bottom with elements made up of atoms which have a simple structure. As we move up the ladder we have elements whose atoms are more and more complex in structure and also heavier in weight.

Let us look at the structure of the atom of the first element on the ladder -- hydrogen. It has one electron circling one proton. The hydrogen atom is made up of one electron and one proton.

If we move up the atomic ladder and add one electron and one proton, we get the second element -- helium. The second element, helium, is made up of an atom with two electrons and two protons.

Let's add another electron and another proton. This will give us the atom of the third element -- lithium. Lithium is made up of an atom with three electrons and three protons.

We could add another electron and another proton to give us the atom of the fourth element and so on up the atomic ladder until we reach the ninety-second element -- uranium.

Uranium is the last element found in nature. It has the most complex atom -- made up of 92 electrons (which we won't take time to count now) circling 92 protons. The uranium atom is also the heaviest atom found in nature -- in addition to having the most complex structure.

Up to now we have talked about the composition of matter -- matter being made up of atoms of the various elements.

What changes can take place in the composition of matter? Matter can undergo two types of changes -- physical change and chemical change. What is the difference between a physical and a chemical change?

In a physical change, the individual molecules remain the same. The molecules do not break down in a physical change. The molecules remain intact.

In a chemical change, the individual molecules break down into atoms to form new substances or new combinations of atoms.

Let's show an example of both types of change. Let's use water -- H_2O as our example.

H_2O is the symbol for the molecule of water; the molecule of water is made of two atoms of hydrogen -- thus H_2 in the symbol -- and one atom of oxygen, or "O".

Let's demonstrate a physical change using water.

Let's melt some ice which is H_2O in a solid form by adding heat to it. We now have water. By adding more heat we can bring the water to a boil producing steam -- still H_2O.

The physical change from ice to water to steam, the molecule H_2O remains the same.

Thus when water undergoes a physical change, the molecule H_2O remains the same. Ice, water, and steam are all made up of the molecule H_2O.

How can we bring about a chemical change in water -- a chemical change in which the molecule of water breaks down into its smaller parts -- the atom of hydrogen (H) and the molecule of water -- H_2O.

By passing an electrical current through water we can decompose or break down water into its component parts -- hydrogen and oxygen. The process is called electrolysis. By the process of electrolysis we can break down the water into hydrogen and oxygen.

Two parts of hydrogen are broken down for every part of oxygen as indicated in the formula H_2O.

We can illustrate how physical and chemical changes differ. The boiling of water produces steam which is a physical change -- because the molecule of H_2O or water still remains. Let us light a match and put it over the steam. The steam puts out the flame -- meaning we still have water or H_2O in steam.

Now let us put a match over the oxygen which has been broken down from water. Hear the pop? The electrolysis produced a chemical change -- changing water or H_2O into two atoms -- hydrogen (H_2) and oxygen (O) which have different properties than water.

The oxygen didn't put out the flame as did the steam. The oxygen having its own properties caused the flame to burn brightly.

What is a physical change? When matter changes its form but the molecule of which it's made remains the same.

When matter changes and the molecule breaks down into separate stoms having different properties -- we have an example of a chemical change.

Let us review what we have covered today.

Chemistry is a study of matter -- we defined matter as anything which has weight and occupies space.

Matter can be divided into smaller parts called molecules.

Molecules are the smallest part of substances which still retain all the properties of the substance.

Molecules can be broken down into smaller parts called atoms.

Atoms are the smallest part of elements that have the properties of elements.

Atoms can be broken down into smaller parts.

An electron with a negative charge circling a nucleus. The nucleus is made up of a proton with a positive electrical charge and a neutron with no charge.

Matter can undergo physical change -- in which molecules stay intact. In chemical changes the molecules break up.

Close - Next time, Mr. Shaffer will tell you more about the physical and chemical changes that matter undergoes.

Script for Control Lesson

Democritus. This Democritus made the very good guess that all matter or all substances were composed of very fine particles and these particles he called atoms. Atoms. Democritus. These particles he called atoms and the word means indivisible. In other words, that they couldn't be divided into any smaller parts. Well, since then we know better but they are named by Democritus as atoms meaning indivisible.

I might mention that these Greek philosophers of that time were great thinkers but they weren't experimenters. They were satisfied just to do the thinking so he didn't go on and prove his thoughts and in this case his guess was good but not exactly correct as we know today. After this then we go through a period of time that mankind more or less stood still. We had the period of Dark Ages. Now we did have chemists at that time but the written word was very small to speak of and many people at that time couldn't read and then, of course, man's greed was entering here and we had the famous alchemists that used to labor trying to turn lead into gold and we know that they never succeeded.

Well, then about 1774 this gentleman here, a French chemist by the name of Lavoisier, Lavoisier, made further studies. His curiosity was aroused and of course we can also mention too, this was the time of the Renaissance, and the fields of all types of learning were starting to show broad gains. People were wanting to learn again. Lavoisier is the man whom we give credit as being the father of chemistry. Lavoisier was also the gentleman who happened to name oxygen, hydrogen, and nitrogen. He also made some very good contributions in the field of combustion. Studying what actually took place in other experiments. But during the French Revolution, being considered an aristocrat even after all his contributions, twenty years after his discovery he was arrested and beheaded.

Well, the next point that comes up in the field of chemistry would be around about the 1800s when this Englishman, John Dalton, an English school teacher, John Dalton, went into the further studies as to what actually made up this matter and these substances. John Dalton is known today as "The Father of the Atomics". He is the man who first stated the atomic theory. Now his atomic theory at that time was not correct and we have found since then in the past 50 years that the atom will react differently than just what Mr. Dalton said. But he is given credit as starting the atomic theory.

The next individual to come up with a gain in the field of chemistry would be the gentleman by the name of Sir Ernest Rutherford. Sir Ernest Rutherford. Sir Ernest Rutherford is the gentleman given the title "The father of the modern atomic theory". He was the one who continued to further break down the first atomic theory started by John Dalton. Sir Ernest Rutherford. We'll talk about that a little later on in the lesson.

Today scientists have learned a great deal about the structure of matter and what makes them up. One of the devices that have been very helpful in this field has been the electron microscope. This electron microscope is very powerful, very strong. It is capable of magnifying matter one hundred thousand times. Even so, the particles of matter are so small that this electron microscope cannot show them. They are so small. Even a molecule of water which is fairly good size.

Well, let's go back a moment now and consider matter and actually how it is made up. What it's like. Let's start with matter and see how it is broken down. If we start with matter, some form of matter, and as you learned in the past, matter is anything that has weight and occupies space. If we take this matter and break it down further then the next smallest particles making up this matter would be molecules. A molecule being the smallest part or particle of that particular compound that still retains the properties of that compound. If we continue to subdivide or to break these molecules down, then this molecule would loose its identity and we would be able to tell then that the next small particle would be the atom that it is made up of. The atom is the smallest particle of an element that still retains the property of that element. You might say, can you break the atom down. Sure you can. We know today that this atom can be further broken down into the parts of the electron, the proton, and the neutron. We'll discuss this a little more in detail here as we go along.

Let's take one particular form of matter. Something very common to all of you. Table salt. Salt that you likely used today for your lunch or that was in your lunch. This common table salt is matter, matter in that it has weight and that it occupies space. We know that it is very tiny, very small. Yet it is a compound made up of particles and if we take this and break it down into the molecule, if we take the smallest particle of this that we can have, it still remains salt. Then we would have a molecule. A molecule that contains two different elements. These two elements would be chlorine and sodium. The smallest particle of this salt that we could still break down and still have, is salt. Not loose the identity. It would have two parts, one part being chlorine, the other part being sodium.

Now to think about just how this would work, we could take a tinker toy, such as this, and show it here. This tinker toy would have the two atoms listed here. The one atom being chlorine, the other atom being the sodium. These two atoms combined together give us the compound salt. Now if you take these particular particles separate by themselves, then we have something completely different. We would have the chlorine in its natural form. It would be a gas such as this, a light green gas that is quite poisonous. It was used during World War I, and too bad that it was because it is very deadly. The other part making up common salt, the other element besides the chlorine gas, is the element sodium. This sodium here does not look anything like salt at all. As a matter of fact, this sodium, if you put it in water, burns with a very fierce intense heat. But, these two atoms combined together give us common table salt. All right, with that in mind, we can go back to the actual structure so far as the molecule is concerned.

These molecules, as you'll remember, are very small, very tiny particles. We have never seem them yet they have different properties to them and we call this the molecular theory. This molecule being the smallest particle of a compound that still retains the identity of these compounds. These molecules are also capable, having properties to them, they are capable of mixing with one another and as you'll see later, we'll show how salt mixes very readily with water, dissolves in it. Then also, keep in mind that molecules are in constant motion. You might have your hand resting on the arm of your chair or on some wooden or metal part of your seat, yet the molecules making up that particular matter of a chair are in constant motion and as you learned earlier from Mr. Shaffer in his discussion of heat, these molecules are in motion and when you add heat to them it speeds them up even faster and then when you have the absence of the heat, they slow down but they never stop; they are in constant motion. This is all part of the molecular theory.

The next part that we want to go into is to take this particular molecule and break it down further so that it loses its identity and if we do this, then we come to the two elements making it up, the chlorine on one hand and, of course, the sodium on the other hand. This, then, was what John Dalton started. You remember the English school teacher; John Dalton and his first atomic theory. Since then we have revised this atomic theory but the atomic theory states that all matter is made up of the atom. To think about the structure of the atom, just think with me for a moment about our own solar system. We have, first of all, the sun which is huge in size and around it we have the planets which are smaller in size and which are orbiting in constant motion around the main mass, the sun. Besides this we also have other celestial bodies, the moon, and other celestial bodies passing around the sun and also through our own solar systems.

The architecture of the atom which Sir Ernest Rutherford first labeled. You remember, Sir Ernest Rutherford, the father of modern atomic physics, first labeled this atom in this manner, very similar to our solar system. The nucleus here in the center, comparable to our sun, we have it composed of neutrons because they are neutral in electrical charge, shown here as the little dot, very fine particle. Also in this mass, the nucleus, we also have other particles known as protons. These protons are actually positive or plus electrical charges. This would be the mass in the center of the atom. Then, orbiting around the outside, just like the planets going around our sun, we have the small little particles known as electrons. These electrons have a negative or a minus electrical charge to them.

Now students, some of you will already realize that besides in one of these atoms, we have other particles in there which we should be aware of, that are still there. We don't want to discuss those as yet. Keeping this in mind then, so far as the atoms go, we can start the wonderful atomic ladder, a ladder of atoms. Take one proton and one electron and we have the first of our elements, hydrogen. Add another electron, another proton, or two electrons and two protons, and we have the next element, helium. Go up to the next step, adding one electron and one proton, and we have the next element, lithium. Continue this same progression of one electron and one proton, and you can go right up the ladder of elements until eventually we come to the heaviest of all of our elements here, 92 electrons, 92 protons, and of course, that will be uranium. Uranium is the heaviest of all of our elements.

As you well know, there are other elements besides this. Elements starting with number 93 and going up to the present day 103. Mankind has succeeded in making these atoms. These particular atoms from 93 up to 103 are man-made or artificial atoms not found in nature. Mankind is still working to discover more of these atoms and I think in the days to follow, we'll see mankind finding more atoms. You'll likely notice that on this chart we have capital letters from our own English alphabet to designate these particular elements. For instance, we have the capital letter O to show oxygen. This is the chemists and scientists shorthand method for writing the various elements. Take the element hydrogen, for instance. Instead of writing out the full word hydrogen, we just use the capital letter H. Mankind can write different formulas much quicker.

You have also noticed on these charts here that there are other letters which are not the first letters of the particular element. In this case, we take the latin words for them and use the first letter of the latin word. Now, if there is a second letter to designate these elements, then the second letter will be a small letter. So, we have this shorthand method for writing different formulas, for writing about different elements.

Let's go back and see about how matter is composed and what happens to it. To do that, we could take some simple thing such as ice, which all of us are quite common with. You know that ice is the unnatural form of water. The ice here is unnatural, a solid, for water. If we take this ice and put it in this arrangement here so that the ice will start to absorb heat energy, remember Mr. Shaffer talking about heat energy, it starts to absorb heat energy, starts to melt, changing from its unnatural form to its natural form as a liquid which we know as water. What we want to notice here is that these molecules, these molecules composing the ice, are made up -- or, will undergo certain changes. In this case it is a physical change, going from a solid to a liquid. I might also add one point, while we're talking about this, that a molecule being so small we can't even see it with the microscope, the electron microscope. As this changes its form, we want it to change from a solid to a liquid. Then, I'll take this bunsen burner and we'll cause heat energy to be directed towards the liquid here and change it from a liquid to a gas. With this in mind, you'll notice that the ice is melting quite nicely. Now, let's take the ice away and you can see just the liquid water here. It has changed from a solid of ice to its normal state as a liquid. We are directing more heat energy to it, changing it from its normal state as a liquid, into a gas. We can show this gas by holding a small plate of glass above it which we will use to collect it in this manner and you can try this in your own home or even in the classroom there, letting that gas strike a cooler surface. This cooler surface, you'll notice, is starting to have little particles on it and here we have taken it from ice in a solid form, let it absorb heat, melt to a liquid, and cause it to change to a gas and then collect it as a liquid.

What kind of a change is this? If you have said that it is a physical change, then you are correct. We could also show another part here where we take and have three test tubes arranged here. All of these test tubes have water in them. We'll put a small amount of salt in these. I want to add the bunsen burner to start these to heating. We'll put a small amount of salt in the first one and also a small amount of sugar into the number two test tube. The third test tube we will leave just plain. Notice that you can actually see the materials here but if we direct the heat to them then you'll notice that they do not show up as such. Just leaving them without the heat, they more or less stay clear. This means that the molecules making up the sugar and the salt have been dissolved in them. You can watch it being driven off. The next thing that we want to go in to will be the chemical change that materials go through. In this case, we want to use the molecules of water. If you continue this, you'll notice that the water is completely driven off and you'll have left there the sugar, which you originally put in, and the salt, which you put in.

To show the chemical change which these molecules will go through, we can take the system here to show the breakdown of this, known as electrolysis. In this we have water on one part, or water in it, to show the decomposition of a molecule of water. Connecting this up with current, the electricity starts this to undergo a change of state. Actually, a chemical change is what it is. You will notice that we have already started a bubbling sensation here at the top. As you can see, we have a small part here and about twice as much over on this side. This will show you that we have two parts coming down here and only one part here. This is the method known as electrolysis to show the decomposition of water, where we have two parts of hydrogen being placed here. The gas is displacing the water, and one part of oxygen displacing the oxygen here. We can test this method to show that it is actually happening, that we do have hydrogen on the one hand and that we do have oxygen on the other hand.

Next time Mr. Shaffer will go into the details on chemical changes.

APPENDIX B

Achievement Tests

1. Tests on "The Effects of Heat"
    a. Preliminary Post-Test pp. B- 2 - B- 6
    b. Immediate Post-Test pp. B- 7 - B- 8
    c. Delayed Post-Test pp. B- 9 - B-12

2. Tests on "Introduction to Chemistry"
    a. Preliminary Post-Test pp. B-13 - B-16
    b. Immediate and Delayed Post-Tests pp. B-17 - B-24

HEAT
Preliminary Post-Test

ACHIEVEMENT TEST

WQED

Junior High School Science Quiz

Form A

Name____________________

School____________________

This is a quiz on how much information you have obtained from books or from school about how heat affects objects.

PART I

Instructions: Briefly answer the questions below in your own words. Write your answers in the lines provided.

1. What happens to objects like pieces of iron or copper when they are heated?

2. In what way will water be affected when heat is removed from it?

3. How do solids, liquids, and gases differ in how heat affects them?

PART II - MULTIPLE CHOICE ITEMS

Instructions: Each of the incomplete statements or questions below is followed by several possible answers.

In the space provided, put a check next to the answer you think is best.

Example:

Water that is heated above the boiling point will

_____ turn into a gas.
_____ remain liquid.
_____ become a solid.

Answer the following items:

1. At room temperature, molecules in objects are

_____ changing shape.
_____ contracting.
_____ moving about.
_____ standing still.

2. The expansion of solids results from a change in molecular

_____ movement.
_____ shape.
_____ size.
_____ state.

3. When an object is cooled its molecules

_____ move at the same rate.
_____ move faster.
_____ move slower.
_____ stop moving altogether.

4. The rate of molecular movement can change in

_____ gases only.
_____ liquids only.
_____ solids only.
_____ gases, liquids, and solids.

5. Which of the following expands most rapidly when heated?

_____ air
_____ alcohol
_____ iron
_____ mercury
_____ water

6. Contraction occurs when heat is removed from

_____ solids only.
_____ liquids only.
_____ gases only.
_____ solids, liquids, and gases.

7. The rate at which objects expand or contract depends on the rate at which their molecules

_____ break up.
_____ move.
_____ change shape.
_____ change size.
_____ change states.

8. Their own rate of expansion is found in

_____ gases only.
_____ liquids only.
_____ solids only.
_____ gases, liquids, and solids.

9. A thermostat works because it is made up of metals which expand

_____ at the same time.
_____ at different times.
_____ at the same rate.
_____ at different rates.

10. Which of the following constitutes an exception to the general rule that objects contract when they cool off?

_____ air
_____ alcohol
_____ ice
_____ mercury
_____ water

11. A pointer thermometer works because its parts are made of metals which

_____ expand at the same rate.
_____ contract at different rates.
_____ contract and expand at the same rate.
_____ contract and expand at different rates.

12. Water is not used in thermometers because as it freezes it

_____ contracts.
_____ expands.
_____ changes state.
_____ evaporates.

13. How many metals does a thermostat use?

_____ 1
_____ 2
_____ 3
_____ 4
_____ 5

14. Matter can exist in how many different states?

_____ 2
_____ 3
_____ 4
_____ 5

15. A practical use of the expansion qualities of a bi-metal bar is found in a(n)

_____ air thermometer.
_____ bell.
_____ bunsen burner.
_____ ice bomb.
_____ thermostat.

HEAT
Preliminary Post-Test

ACHIEVEMENT TEST

WQED

Junior High School Science Quiz

Form B

Name________________________

School________________________

This is a quiz on how much information you have obtained from books or from school about how heat affects objects.

PART I

Instructions: Briefly answer the questions below in your own words. Write your answers in the lines provided.

1. What happens to the molecules in an object when the object is heated?

2. What happens to the size or shape of a heated object when the object is cooled?

3. What change of state occurs in water when heat is removed from it?

PART II - MULTIPLE CHOICE ITEMS

Form A items were used.

ACHIEVEMENT TEST

HEAT
Immediate Post-Test

WQED
Junior High School Science
Form A

Name__________________________ Grade__________
7th or 8th

School__________________________

Mr. Shaffer showed you several demonstrations.

For example, he showed a picture of moving arrows. This illustrated the idea that molecules in a drop of water are moving.

PART I

Instructions: In your own words describe the idea Mr. Shaffer was demonstrating with each of the following experiments.

1. Heating Benjamin Franklin's pulse glass with his hands.

2. Applying heat to a thermostat hooked up to a bell.

3. Heating the empty glass ball that produced bubbles in a beaker of water.

4. Passing steam through a condenser.

5. The ball wouldn't pass through the ring when it was heated. Why?

6. After the ball was dipped into cold water, the ball was able to pass through the ring. Why?

PART II

1. Explain in your own words what happens to the molecules in a liquid when you heat the liquid.

HEAT
Immediate Post-Test

ACHIEVEMENT TEST

WQED
Junior High School Science
Form B

Name______________________________ Grade____________
School____________________________ 7th or 8th

Mr. Shaffer showed you several demonstrations.

For example, he showed a picture of moving arrows. This illustrated the idea that molecules in a drop of water are moving.

PART I

Instructions: In your own words describe the idea Mr. Shaffer was demonstrating with each of the following experiments.

1. Heating Benjamin Franklin's pulse glass with his hands.

2. Applying heat to a thermostat hooked up to a bell.

3. Heating the empty glass ball that produced bubbles in a beaker of water.

4. Passing an electric current through a wire with a weight attached to it.

5. Heating water in a test tube.

6. Colored water rising up the tube when the flask of water was heated.

PART II

1. Explain in your own words just why it is that a bi-metal bar bends when it is heated.

ACHIEVEMENT TEST

HEAT
Delayed Post-Test

WQED
Junior High School Science
Form A

Name________________________ Grade__________
School________________________ 7th or 8th

PART I - FILL-INS 10 minutes

Instructions: In the blanks below, fill in the word or words which makes the sentence correct and complete.

Example: Water heated above the boiling point will turn into __________. (Write in your answer; if you write steam, you are correct.)

Fill in the blanks in the following sentences:

1. The state of matter which expands the most when heated is a __________.
2. An increase in the ________ of molecules will cause an object to expand.
3. We can cause an object to contract by removing ___________ from it.
4. The part of a thermostat which is heated and cooled is made of a __________.
5. The substance which expands as it reaches the freezing point is ________.
6. A liquid can be turned into a solid by ___________ heat.
7. In your own words, explain how expansion and contraction can be brought about.

PART II: MULTIPLE CHOICE - 5 minutes

Instructions: Each of the incomplete statements or questions below is followed by several possible answers. In the space provided, put a check next to the answer you think is best.

Example: Water that is heated above the boiling point will turn into

_____ a solid.
_____ steam.
_____ ice.

Answer the following items:

1. The contraction of solids results from a change in molecular

_____ movement.
_____ size.
_____ both of these.
_____ neither of these.

2. Which of the following expands most rapidly when heated?

_____ air
_____ iron
_____ liquid alcohol
_____ mercury
_____ water

3. Contraction occurs when heat is removed from

_____ gases only.
_____ liquids only.
_____ liquids and gases.
_____ liquids and solids.
_____ liquids, gases and solids.

4. How many metals are used in the part of the thermostat that is heated?

_____ 1
_____ 2
_____ 3
_____ 4
_____ 5

5. At certain temperatures, which of the following shows an exception to the general rule that objects keep contracting when they cool off?

_____ air
_____ iron
_____ liquid alcohol
_____ mercury
_____ water

6. When you add heat which of the following will expand the most?

_____ metal
_____ water
_____ air
_____ all about equally

7. A practical use of the expansion qualities of a bi-metal bar is found in a(n)

_____ air thermometer.
_____ bell.
_____ bunsen burner.
_____ thermostat.
_____ all of the above.

8. Water is not used in thermometers because ~~as~~ it begins to freeze it

_____ contracts.
_____ expands.
_____ changes state.
_____ contracts and changes state.
_____ none of the above.

9. When heat is applied, which of the following changes of state occur?

_____ gases turn into solids
_____ gases turn into liquids
_____ liquids turn into gases
_____ liquids turn into solids
_____ all of the above

10. A thermostat works because it is made up of metals which expand

_____ at the same time.
_____ at different times.
_____ by the same amount.
_____ by different amounts.

HEAT
Delayed Post-Test

ACHIEVEMENT TEST

WQED
Junior High School Science
Form B

Name____________________________

School__________________________

Grade______________
7th or 8th

PART I - FILL-INS 10 minutes

Instructions: In the blanks below, fill in the word or words which make the sentence correct and complete.

Example: Water heated above the boiling point will turn into __________. (Write in your answer; if you write steam, you are correct.)

Fill in the blanks in the following sentences:

1. The state of matter which contracts the least when cooled is a ________.
2. A decrease in molecular motion will cause an object to __________.
3. By applying ___________ to an object we can speed up the motion of its molecules.
4. Two metals with different expansion rates are fused together into a single bar. If we heat the bar, it will ____________.
5. Water is not used in thermometers because as it begins to freeze it ______________.
6. If we remove heat from a gas, the gas will turn into a ___________.
7. In your own words, describe what changes of state occur when you add heat and when you remove heat.

PART II - MULTIPLE CHOICE ITEMS

Form A items were used.

CHEMISTRY
Prelimenary Post-Test

ACHIEVEMENT TEST

WQED

Junior High School Science Quiz

Name ____________________

School ____________________

Instructions: Mr. Lee showed you some demonstrations and illustrations. For example, he showed you how the letters of the alphabet stand for chemical elements.

This demonstrated how chemists use a shorthand way to represent chemical elements.

In your own words, describe the idea Mr. Lee was illustrating with the following demonstrations.

1. The use of the tinker toy.

2. The chart showing an atom's structure.

3. The chart of atomic elements.

4. The melting of ice, and the boiling of water.

5. The boiling of sugar in water and salt in water.

6. The electrolysis of water.

PART II - MULTIPLE CHOICE ITEMS

Instructions: Each of the incomplete statements or questions below is followed by several possible answers.

In the space provided, put a check next to the answer you think is best.

Example: Water that is heated above the boiling point will turn into

_____ a solid.
_____ steam.
_____ ice.

Answer the following questions

1. The man who gave the name atom to the small particles in matter was

_____ Dalton.
_____ Democritus.
_____ Lavoisier.
_____ Rutherford.

2. The man who is called "the father of modern chemistry" discovered

_____ carbon.
_____ helium.
_____ lithium.
_____ oxygen.
_____ all of the above.

3. The part of the atom which has a positive charge is called a(n)

_____ electron.
_____ neutron.
_____ nucleus.
_____ proton.
_____ none of the above.

4. The nucleus of an atom is made up of

_____ neutrons and electrons.
_____ neutrons and protons.
_____ protons and electrons.
_____ neutrons only.
_____ protons only.

5. The element which is made up of one electron and one proton is called

_____ helium.
_____ uranium.
_____ nitrogen.
_____ oxygen.
_____ none of the above.

6. The makeup of an atom consists of a(n)

_____ neutron circling a proton and an electron.
_____ proton circling a neutron and an electron.
_____ electron circling a neutron and a proton.
_____ neutron circling a nucleus.
_____ none of the above.

7. As you go up the atomic ladder each element adds

_____ one neutron and one proton.
_____ one neutron and one electron.
_____ one electron and one proton.
_____ none of the above.

8. How many protons and electrons does the first man-made atom have?

_____ 1
_____ 14
_____ 92
_____ 93
_____ 103

9. The heaviest element found in nature is

_____ helium.
_____ lithium.
_____ mercury.
_____ oxygen.
_____ uranium.

10. The lightest element found in nature is

_____ chlorine.
_____ hydrogen.
_____ nitrogen.
_____ sodium.
_____ none of the above.

11. The smallest part in a substance like salt which has all the properties of salt is called a(n)

_____ atom.
_____ electron.
_____ molecule.
_____ element.
_____ nucleus.

12. The composition of water consists of

_____ one part H and one part O.
_____ one part H and two parts O.
_____ two parts H and one part O.
_____ two parts H and two parts O.
_____ none of the above.

13. An example of a chemical change is found in

_____ sugar dissolving in water.
_____ the decomposition of water.
_____ water turning to steam.
_____ ice melting.
_____ the isolation of a molecule of salt.

14. The smallest part of an element that has the properties of that element is a(n)

_____ atom.
_____ electron.
_____ molecule.
_____ neutron.
_____ nucleus.

15. We define a chemical change as one in which a substance

_____ breaks up into elements having different properties than the original substance.
_____ breaks up into elements having the same properties as the original substance.
_____ changes its state.
_____ is dissolved in a universal solvent.

CHEMISTRY
Same Day Post-Test

ACHIEVEMENT TEST

WQED

Junior High School Science Quiz

Name ____________________

School ____________________

Grade ____________
7th or 8th

Instructions: Mr. Lee showed you some demonstrations and illustrations. For example, he showed you how the letters of the alphabet stand for chemical elements.

This demonstrated how chemists use a shorthand way to represent chemical elements.

In your own words, describe the idea Mr. Lee was illustrating with the following demonstrations.

1. The use of the tinker toy.

2. The picture of the atom's structure.

3. The chart showing all the elements.

4. The melting of ice; and the boiling of water.

5. The electrolysis of water.

II.

1. What are the names of the parts of an atom?

2. What is the electrical charge of each part of the atom?

3. What is an atom?

CHEMISTRY
Next Day Post-Test
and
Delayed Post-Test

ACHIEVEMENT TEST

WQED
Junior High School Science
Form A

Name ____________________

School ____________________

Grade ____________
7th or 8th

Part I - FILL-INS - 9 minutes

Instructions: In the blanks below, fill in the word or words which make the sentence correct and complete.

Example: Water heated above the boiling point will turn into ________. (Write in your answer; if you write steam, you are correct.)

1. If water is broken down into its component elements we will get ________ parts of ________ to one part of ________.

2. As you go up the atomic ladder each new element adds one ________ and one ________.

3. The smallest particle of a substance or compound like salt that retains the properties of salt is a(n) ________.

4. When we melt ice to form water we have brought about a ________ change.

5. The part of the atom which has no electrical charge is called a(n) ________.

6. Give the chemist's symbol or formula for each of the following:

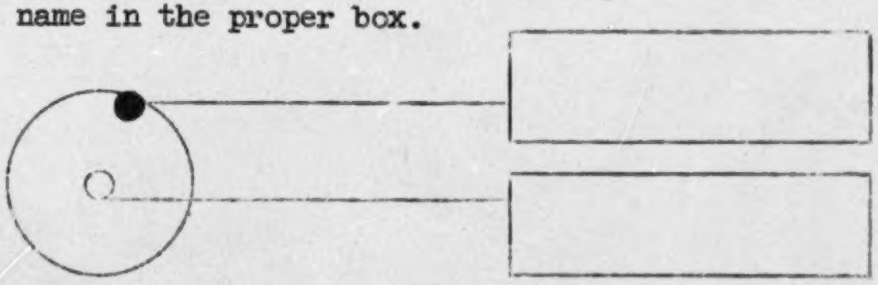
hydrogen ________
oxygen ________
sodium ________
chlorine ________

helium ________
salt ________
water ________

7. Electrolysis is the process in which water can be broken down into ________ and ________.

8. The element found in nature which has the smallest number of electrons and protons is ________.

9. In this diagram of a hydrogen atom, label the 2 particles shown by filling in its name in the proper box.



10. In a chemical change the ________ break up into the ________ of which they are composed.

11. What is the heaviest natural element? ________

12. What are the two fundamental properties of matter? ________ ________

PART II - MULTIPLE CHOICE ITEMS 6 minutes

Instructions: Each of the incomplete statements or questions below is followed by several possible answers. In the space provided, put a check next to the answer you think is best.

Example: Water that is heated above the boiling point will turn into

_____ a solid.
_____ steam.
_____ ice.

Answer the following questions

1. The part of the atom which has a positive charge is called a(n)

_____ electron.
_____ neutron.
_____ proton.
_____ nucleus.
_____ particle.

2. Which of the following is the largest component of matter?

_____ atom
_____ molecule
_____ neutron
_____ nucleus
_____ proton

3. The second element on the atomic ladder has

_____ two protons.
_____ two electrons.
_____ one proton and two electrons.
_____ one electron and two protons.
_____ two protons and two electrons.

4. We define a chemical change as one in which a substance breaks up into substances

_____ having different properties than the original substance.
_____ having the same properties as the original substance.
_____ which have changed states.
_____ none of these.

5. The smallest part of an element that has properties of that element is called a(n)

_____ atom.
_____ electron and neutron.
_____ molecule.
_____ nucleus.
_____ neutron and proton.

6. How many molecules would there be in a drop of water?

_____ one
_____ about ten
_____ many thousands

7. The man who gave the name atom to the small particles of matter was

_____ Dalton.
_____ Democritus.
_____ Lavoisier.
_____ Rutherford.

Free Response

1. What is a molecule?

2. What is a chemical change?

CHEMISTRY
Next Day Post-Test
and
Delayed Post-Test

ACHIEVEMENT TEST

WQED
Junior High School Science
Form B

Name ____________________

School ____________________

Grade ____________
7th or 8th

Part I - FILL-INS 9 minutes

Instructions: In the blanks below, fill in the word or words which make the sentence correct and complete.

Example: Water heated above the boiling point will turn into ______. (Write in your answer; if you write steam, you are correct.)

1. We may define matter as anything that has ________ and occupies ________.
2. By adding one electron and one proton we go up the atomic ladder and arrive at a different ________.
3. The smallest particle of an element like oxygen that retains the properties of oxygen is a(n) ________.
4. When we break water down into hydrogen and oxygen we have brought about a ________ change.
5. The part of the atom which has a positive charge is called a(n) ________.
6. Give the chemist's symbol or formula for each of the following:

   hydrogen ________
   oxygen ________
   sodium ________
   chlorine ________
   helium ________
   salt ________
   water ________

7. Water may be broken down into hydrogen and oxygen by a process known as ________.
8. Uranium is the element found in nature which has the most ________ and the most ________.
9. How many protons in one atom of hydrogen? ________
   How many electrons in one atom of hydrogen? ________
10. What kind of particles are in the nucleus of an atom? ________
11. What kind of particles in an atom circle in orbits around the nucleus? ________
12. Which of these is the largest -- a proton, an atom or a molecule? ________
    Which one is the smallest? ________
13. In the space at the right, draw a picture that shows the structure of a hydrogen atom, and label the parts.

PART II - MULTIPLE CHOICE ITEMS 6 minutes

Instructions: Each of the incomplete statements or questions below is followed by several possible answers. In the space provided, put a check next to the answer you think is best.

Example: Water that is heated above the boiling point will turn into

_____ a solid.
_____ steam.
_____ ice.

Answer the following questions

1. When molecules of common salt break up into elements we get

_____ sodium and chlorine.
_____ hydrogen and chlorine.
_____ hydrogen and sodium.
_____ oxygen and sodium.
_____ none of the above.

2. Matter may be broken down into

_____ atoms.
_____ molecules.
_____ electrons, protons, neutrons.
_____ all of these.
_____ none of these.

3. The element which is made up of one electron and one proton is called

_____ helium.
_____ hydrogen.
_____ lithium.
_____ sodium.
_____ chlorine.

4. The part of the atom which has a negative charge is called a(n)

_____ electron.
_____ neutron.
_____ proton.
_____ nucleus.
_____ particle.

5. The man who is called "the father of modern chemistry" gave the name to the element

_____ carbon.
_____ chlorine.
_____ helium.
_____ lithium.
_____ oxygen.

6. The lightest element found in nature is

_____ chlorine.
_____ hydrogen.
_____ lithium.
_____ oxygen.
_____ sodium.

7. The smallest part in a substance like salt which has all the properties of salt is called a(n)

_____ atom.
_____ electron and neutron.
_____ element.
_____ molecule.
_____ nucleus.

Free Response

1. What is a molecule?

2. What is a physical change?